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MR. JOHN BIRKINBINE, President, in the chair.

TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

BY

ALBERT CUSHING CREHORE, PH.D.,
Assistant Professor of Physics, Dartmouth College,

AND

GEORGE OWEN SQUIER, PH.D.,
First Lieutenant of Artillery, U. S. Army; Instructor Department of Electricity and Mines, U. S. Artillery School.

In April, 1897, a paper* was read before the American Institute of Electrical Engineers, describing the general princi-

* The Synchronograph; a New Method of Rapidly Transmitting Intelligence by the Alternating Current.

ples of the synchronograph and the experiments at that time completed in developing it. As stated therein, the next step desirable was to test the system upon long telegraph lines having considerable distributed capacity, the length of the only line used up to that time being thirteen miles. Since then opportunity has been presented to make these trials on actual lines of considerable lengths and having different distributed capacities. Through the courtesy of Mr. W. H. Preece, Engineer-in-Chief of the British Postal System, every facility has been afforded for conducting the experiments on the telegraph lines of the British Government.

The tests were made over loops of varying lengths from the General Post Office, London, where both transmitters and receivers were located. The lines can best be used for experimental purposes on Sundays, and the tests were made on two dates, viz., August 8th and 22d, 1897, when the lines were available throughout the day. Mr. A. Eden, of the technical staff of the Engineer-in-Chief, assisted throughout these experiments, and his experience and assistance in conducting the trials were invaluable.

The apparatus available for experiment was more extensive than would usually be found in a laboratory. There was a high frequency alternator of wide range giving practically harmonic waves, from 50 to 720 complete waves per second; actual telegraph lines with values* of KR varying from 0 to 261,000 and resistance varying from 0 to 10,000 ohms; an artificial submarine cable representing to within 1 per cent. of accuracy, an actual cable of 180 knots in length, and also the latest types of Wheatstone transmitters and receivers, with adjustable condensers, etc.

The longest loop tried was 1,097 miles, from London to Glasgow, Aberdeen, Edinburgh, and return to London by a different pole line, as indicated on the map, *Fig. 4*. This contained some iron wire and also 48 miles of underground cable, and a total value of KR equal to 261,000.

It was found in the course of trials with the different apparatus that it was possible to operate the Wheatstone receiver

* The value of R is in ohms; K is in microfarads.

without alteration by means of the synchronograph, and a test was made over the longest line to compare the efficiency of the two transmitters when operating the same receiver under identical conditions of line. The surprising result was discovered that the synchronograph could operate the Wheatstone receiver approximately *three* times as fast as the Wheatstone transmitter on any line, provided the mechanical limit of the receiver is not already reached. The Wheatstone system

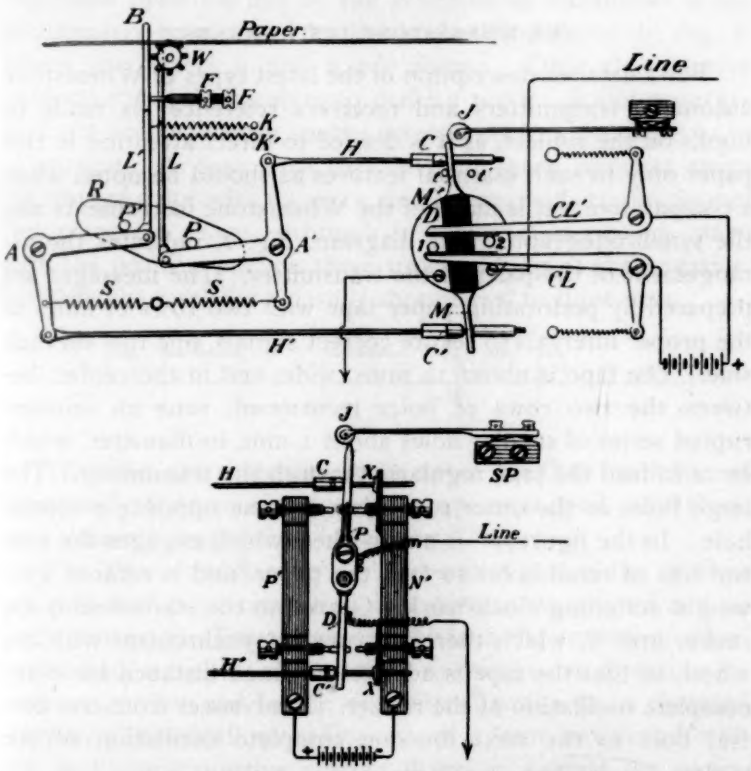


FIG. 1.—Diagram of the Wheatstone transmitter.

operated from London to Aberdeen ordinarily employs two automatic repeaters to increase the speed. Without any repeaters the synchronograph operated the Wheatstone receiver over this line practically up to its mechanical limit. By the synchronograph method of transmission it thus becomes pos-

sible to operate Wheatstone receivers at the present speeds without repeaters anywhere in the British Islands.

One of the most important results of the trials to be described has been to emphasize the probability that the sine wave possesses superiority over other forms of wave for any speed, slow or fast.

To make the experiments more clearly understood, a brief description of the Wheatstone instruments is given.

THE WHEATSTONE INSTRUMENTS.

For a detailed description of the latest types of Wheatstone automatic transmitters and receivers reference* is made to books on the subject, as it is desired to direct attention in this paper only to such essential features as should be noted when a comparative test is made of the Wheatstone instruments and the synchronograph. The diagram, *Fig. 1*, indicates the arrangement of the parts of the transmitter. The messages are prepared by perforating paper tape with two rows of holes at the proper intervals to secure correct signals, one row on each side. The tape is about 12 mms. wide, and in the center, between the two rows of holes mentioned, runs an uninterrupted series of smaller holes about 1 mm. in diameter, which serve to feed the tape regularly through the transmitter. The large holes in the outer rows always come opposite a central hole. In the figure, *W* is a star-wheel which engages the central line of small holes to feed the paper, and is rotated by a weight actuating clock-work. Geared to the star-wheel is the rocker arm *R*, which therefore runs in synchronism with the wheel, so that the tape is advanced a fixed distance for every complete oscillation of the rocker. It advances from one central hole to the next for one complete oscillation of the rocker.

A characteristic of the transmitter is the fact that the contact for the electrical circuits is not made through the holes in the paper as in some transmitters; but by the small steel rods *LL'*, which pass through the holes in the paper, contacts are

*American Telegraphy, by W. Maver, Jr., published by Maver & Co., New York, page 296.

made and broken in another part of the apparatus by means of the levers AA' and rods HH'. For every complete oscillation of each rod L or L', including an up-and-down motion, the battery connections are twice reversed, and as the rods move in synchronism with the paper tape, the distance between consecutive holes in the tape when continuous rows are perforated corresponds to two reversals or to one complete wave of electromotive force. The wave of electromotive force impressed upon the line by the Wheatstone transmitter is approximately represented by the broken line shown in *Fig. 2*, where the letters *a* and *b* are shown. Only the positive currents cause the receiver to make a mark. A dot together with the accompanying space corresponds to a complete wave of current. A dash with its following space occupies twice the time of a dot with its space, and corresponds to the time of two complete waves, although in reality it is a single wave with the positive portion three times as long as the negative, and thus the mark for a dash is about equal to three dots.

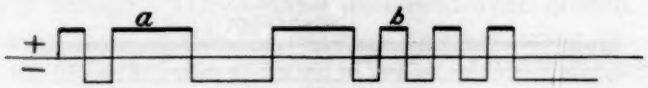


FIG. 2.

The chief characteristics to be noted are that the waves of impressed electromotive force are square-topped, and those for a dash are longer than for a dot.

The Wheatstone Receiver.—An essential part of the receiver is a polarized relay consisting of a permanent magnet and an electro-magnet. The armature, to which the recording-wheel is attached, is by this arrangement moved in one direction for a direct current and in the opposite direction for a reversed current. The small recording-wheel is kept moistened with ink, and every positive current drives it against the paper, while a negative one raises it from the paper. The paper tape is driven forward by clock-work, the speed of which is controlled by an ingenious device, and thus a series of marks is made upon the tape corresponding to the positive portions of any set of current waves. For a wave like that in *Fig. 2* there would be dots and dashes received forming the letters *a* and

b. By this receiver only one mark is made upon the paper during a complete wave of current consisting of a positive and negative portion. The reverse currents are not used for making marks on the paper.

The electro-magnet of the receiver consists of two solid soft-iron cores wound with spools of wire on the differential plan. To give the two coils exactly opposite magnetic effects for duplex working, the two wires are wound together as one upon the spools. The resistance of each coil is made equal to 100 ohms in the British service. They may be connected in different ways when not used for duplex working, with the coils in series making 200 ohms, or in parallel making 50 ohms for the instrument.

In practice it is found that, when connected directly to the line and the return, and operated by the transmitter, the

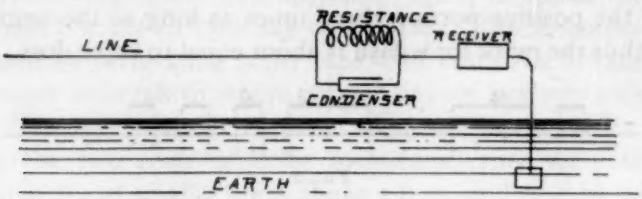


FIG. 3.

speed obtainable over most lines can be increased by the use of condensers properly arranged. The arrangement of condensers and resistance in actual use in England is indicated by *Fig. 3.* Common values of the resistance and capacity are about 8,000 ohms and 10 to 20 microfarads, which would vary according to the line.

DESCRIPTION OF THE EXPERIMENTS.

The apparatus was mounted in the experimental room in the General Post Office, London, which is conveniently wired for such tests, so that the terminals of any line can be connected to the room from the switchboards in the operating rooms above. The details of the experimental transmitter used were practically the same as those employed in the original experiments, and described in the first paper to which reference

is made. This part of the apparatus, however, was constructed specially for these experiments by Elliott Bros. of London. The messages were prepared by fastening strips of paper upon the metal surface of a large wheel geared directly to the shaft of the alternator as before described.

As it was desired to make tests over a considerable range of frequencies, the adaptability of the small Pupin alternator used in the first experiments justified cabling for this particular machine, which was loaned a second time for these trials. The alternator was driven by a 1 horse-power Lundell motor from hundred-volt constant potential mains, which were wired for the purpose from the dynamos used for lighting the building, and a storage battery was available for the excitation of the rotating field of the generator. Since the generator is in fact four alternators of 18, 22, 26 and 30 poles respectively, and the motor could be run regularly at very slow speeds as well as high, this combination with a field excitation, which could be varied at will, permitted a wide range of frequencies at any desired voltage. Transformers were used when desired. For the most rapid speeds the chemical receiver, using the same formula of Delany and operated in the simple manner described in the first paper, was employed with the synchronograph. The paper was prepared and used in the form of sheets instead of tape.

The preparations for the first trials over actual lines, which were made on Sunday, August 8, 1897, included a series of observations to determine the variations of a voltmeter of the magnetic type, with changes of frequency. For this purpose the Kelvin multicellular electrostatic voltmeter of the General Post Office was used for comparison, and observations taken over a range of frequencies from 200 to 610, and curves plotted by which any given reading of the instrument could be read as true volts. The unreliability of instruments of this magnetic type, when used for frequencies outside of that for which they are designed, is well known, and for a frequency of 610 the readings were but 73 per cent. of those of the electrostatic instrument, while for a frequency of 325 this was increased to 94 per cent., the readings coinciding at a frequency below the latter.

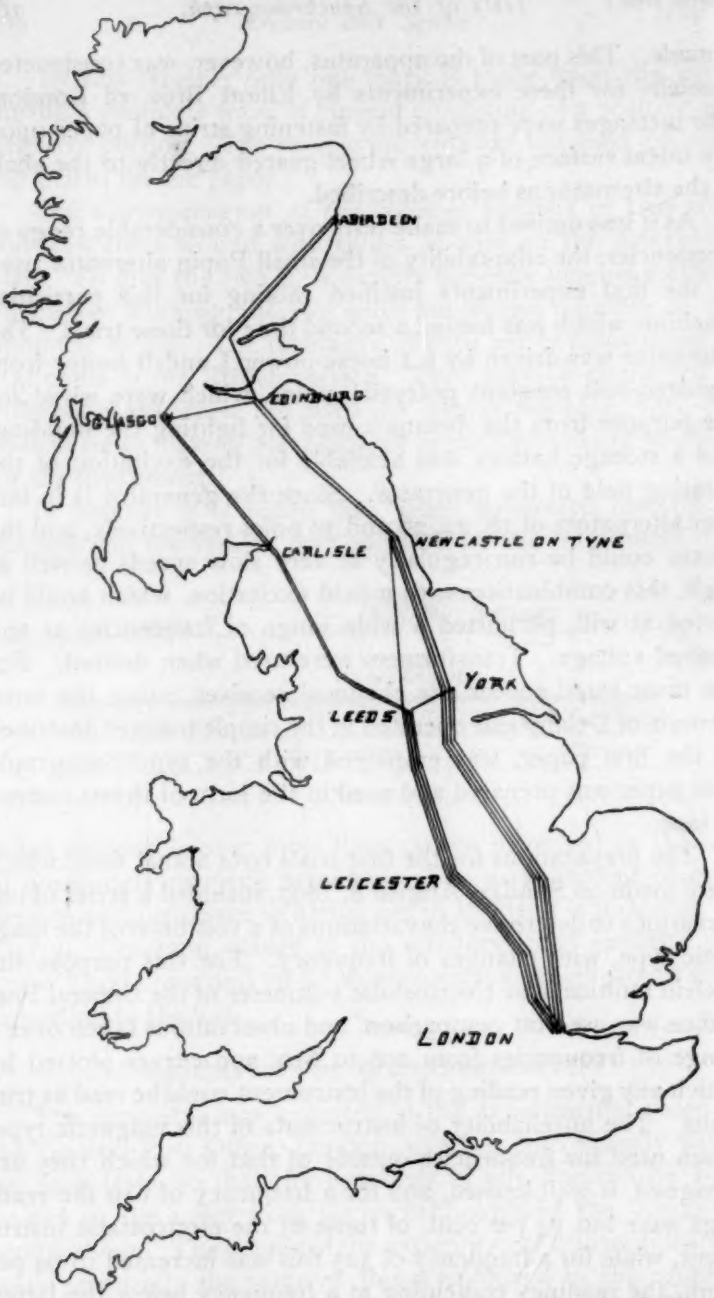


FIG. 4.—Map showing routes of lines used on August 8th and 22d, 1897.

Since the curves plotted from the observations with the electrostatic instrument proved to be straight lines passing through the origin, showing that the voltages are proportional to the speeds with constant excitation, the readings of the electrostatic instrument were probably correct.

SUNDAY, AUGUST 8, 1897.

The location of each of the four lines used is shown in the accompanying map, *Fig. 4*. The first line was from London *via* Leeds to Newcastle-on-Tyne, and return to London *via* York. The data are given in the following table:

Section.		Mileage.		R	K		Total K	K R
From	To	Open	Covered	B A Units	Open	Covered		
London	Leeds	202·88	2·83	550	3·04	·76	3·80	2090
Leeds	London via Newcastle-on-Tyne.	356·14	36·08	3770	5·34	9·73	15·07	56814
		559·02	38·91	4320	8·38	10·49	18·87	81518

From London to Leeds, copper wire, 400 pounds per mile; diameter, ·158 inch; resistance, R = 2·225 ohms per mile.

From Leeds to London, *copper wire*, 200 pounds per mile; diameter, ·112 inch; *R* = 4·45 ohms per mile; except 82¾

FIG. 5.

miles of *iron wire*, 400 pounds per mile, diameter, ·171 inch. *R* = 14 ohms per mile.

K for copper wire 200 pounds per mile = ·0150 microfarads per mile.

K for copper wire 400 pounds per mile = ·0156 microfarads per mile.

NOTE:—**The capacities given are for a line with earth connection at both ends, and when this is not the case, the circuit being a simple metallic loop, it is considerably reduced in value. When the loop is of the kind described, having the going and returning conductors separated by several miles instead**

of being upon the same poles, it is seen that the total distributed capacity of the loop is approximately a quarter of its value when the earth connection is used. Let the point *A*, *Fig. 5*, represent the cross-section of the direct conductor, and *B*, that of the return, the distance between *A* and *B* being large as compared with their distance from the earth. When the line is earth-connected as represented by either diagram in *Fig. 6*, the capacity is taken from the conductor to earth all the distance around the loop; for one plate of the condenser is the whole conductor, and the other plate the earth. Let the capacity per mile when earth is used be denoted by k, and the length of the whole loop in miles by m. Then, if the total capacity is K, we have

$$K = km \text{ when earth-connected.}$$

If no connection is made to the earth, and the circuits are as represented in *Fig. 7*, then the capacity of the system is taken from one conductor to the other instead of to earth. Hence one plate of the condenser is the outgoing conductor *A*, and the other plate the return conductor *B*. The capacity from

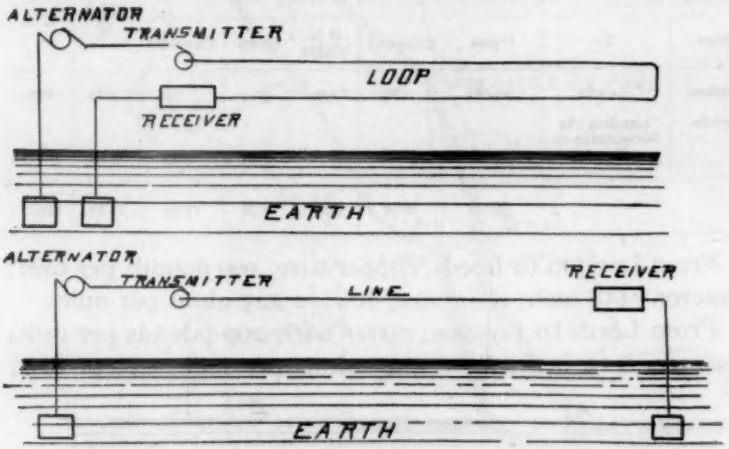


FIG. 6.

A to *B* when separated several miles is different from that when they are on the same poles near together. The earth is a neutral conductor comparatively near to each conductor *A* and *B* and has upon it equal charges of the opposite polarity, one kind being under conductor *A* and the opposite kind under *B*, each being equal to the charges upon the wires *A* and *B*. The capacity of the condenser from *A* to *B* is therefore equal to the capacity of two condensers in series having a capacity of k per mile. The equivalent capacity K' of condensers in series is

$$K' = \frac{1}{\Sigma \frac{1}{k}}.$$

In this case the condensers in series are but two in number and of equal capacity k per mile, hence

$$k' = \frac{1}{2} k$$

The length of one plate of the condenser is only equal to the return conductor so that the whole capacity of the loop when not earth-connected is

$$K' = \frac{k}{2} \times \frac{m}{2} = \frac{1}{4} K$$

or one-quarter of the capacity when earth-connected.

Although the capacity of the system is the same in the two diagrams of *Fig. 6*, the earth intervenes between transmitter and receiver in one instance while it does not in the other, and there is theoretically a difference between the wave propagation in the two cases, the velocity in the earth, however, being approximately the velocity of light. The difference is so slight that it has no appreciable effect in practice. This question has been settled by years of experience with the Wheatstone system since it is known that the speed of operation is practically the same whether the instruments be side by side or separated by the whole length of the line, provided the capacity times the resistance is the same in the two cases.

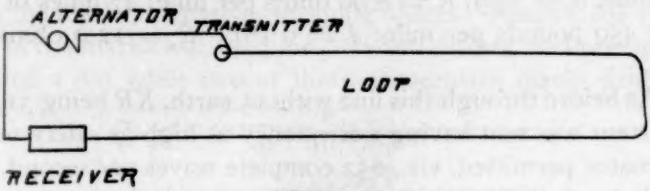


FIG. 7.

The value of *KR* in the line to Newcastle-on-Tyne when not earth-connected was, therefore, 20,380 instead of 81,518, and the one loop was employed as two distinct lines. When earth is used it is approximately equivalent to a line using earth return equal in length to the entire loop, and when not earth-connected it is equivalent to an actual line using earth return of half the length of the loop.

With no earth, messages were received with ease at a frequency of 652 or 1,304 alternations per second. This frequency was limited by the fact that the greatest number of poles to the generator was 30 and the number of revolutions to produce this frequency was 2,608, beyond which it was not then thought advisable to go for fear of injuring the machine.

With earth and a total value of *KR* equal to 81,518, a frequency of 165 or 330 alternations per second was reached.

To obtain a longer line with a greater value of *KR*, a second loop was made up as follows:

Section.		Mileage.		R	K		K	K R
From	To	Open	Covered	B A Units	Open	Covered		
London	Glasgow	402·72	8·74	1075	6·04	2·36	8·40	9030
Glasgow	London via Edinburgh	417·84	35·30	4185	6·24	9·52	15·76	65956
		820·56	44·04	5260	12·28	11·88	24·16	127082

Route.—London *via* Leeds to Glasgow, and return *via* Edinburgh, Newcastle-on-Tyne, and York to London.

London to Glasgow 400 pounds per mile, copper wire. $d = \cdot158$ inch. $R = 2\cdot225$ ohms per mile.

Glasgow to London, 86 miles of copper wire, 100 pounds per mile, $d = \cdot079$; $R = 8\cdot90$ ohms per mile; 47 miles of iron wire 450 pounds per mile; $d = 0\cdot181$. $R = 12\cdot0$ ohms per mile.

As before through this line without earth, KR being 31,771, a current was sent having a frequency as high as safety to the alternator permitted, viz., 652 complete waves per second, and no limit of speed due to the line was reached, the messages being received with perfect clearness. With earth and $KR = 127{,}082$, no records were received at all on this date on account of not having at hand a suitable transformer to produce high enough potential at the slow speed of the alternator necessary. Before the next trials were made a suitable transformer was available to deal with a value of KR much larger than the above.

To test the fact that the messages were actually passing through Glasgow, and that the records were not being caused by leakage currents across the line at some point, an experiment was made of breaking the circuit by the operator at Glasgow at a certain time and restoring it again five minutes later. Before and after the line was so broken the messages were transmitted readily, while during the time it was broken not the slightest record could be obtained.

An instructive experiment, illustrating forcibly the influence of increase of distributed capacity upon ærial wires, was that of suddenly plugging in and out the earth connection,

thereby practically changing the length of the line two-fold, when at the instant the earth was connected the motor would slow down and labor under the increased load.

THE SYNCHRONOGRAPH AND WHEATSTONE RECEIVER.

On Thursday, August 12th, it was decided to try the synchronograph with the Wheatstone receiver, which was at hand in the same room. This was done, and without any alteration of the receiver whatever it responded readily to each wave of current from the alternator. Messages were then correctly transmitted and received. This was done by two different methods. First, the messages were interpreted by the portions of current omitted, as described in the former paper, the omission of a single mark denoting a dot and two marks a dash, the marks themselves meaning spaces. Second, the presence of the marks was used for dots and dashes, and one mark denoted a dot while two or three consecutive marks denoted

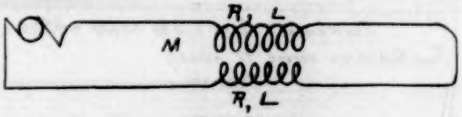


FIG. 8.

a dash. The marks are all regularly spaced, and the eye experiences no difficulty in reading the dash, even though it is made up of two or three separate consecutive marks instead of a single long mark, since the length of the dash is of more moment than the continuity of the mark.

These preliminary tests developed the fact that messages could be received by the Wheatstone receiver in the laboratory faster with the synchronograph than with the regular Wheatstone transmitter. When this discovery was made the Engineer-in-Chief desired to make a more extensive series of experiments and try the synchronograph with the Wheatstone receiver over actual lines having a value of $K\,R$ sufficient to reduce the speeds. As the Wheatstone receiver was to be used with the alternating current, the first thing wanted was a knowledge of its constants. The inductance of the instrument measured by the impedance method was found to be ·875 henry for a single coil and 3·46 henrys for the coils in series.

When the coils were connected so as to give opposing magnetic effects the measurements gave an inductance of ·187 henry. The two coils of the receiver are wound together, the two wires being wound as one upon the spools in such close proximity that the mutual induction between the coils is at its maximum, and is nearly equal to the inductance of each coil. In such a case the inductance of the two coils in series should equal four times that of a single coil if there were no magnetic leakage, and when connected in opposition the inductance would vanish. This agrees approximately with the measurements when allowance is made for small magnetic leakage.

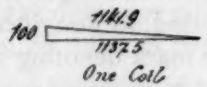


FIG. 9.

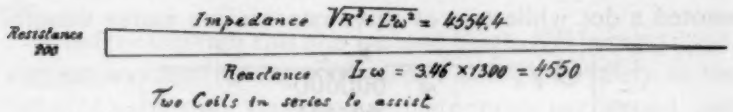


FIG. 10.

FIG. 11.

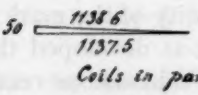


FIG. 12.

The circuit is represented in *Fig. 8* where the two coils of the receiver are represented in series and also in mutual relation.

When the receiver coils are connected in parallel the inductance is practically the same as that of a single coil, since the two coils are like a single one having larger wire, the number of turns being identical.

Figs. 9, 10, *11* and *12* illustrate the relations between the impedances, resistances and reactances of the Wheatstone re-

ceiver coils when connected in different ways. *Fig. 9* is for a single coil alone, *Fig. 10* the two connected in series to assist, *Fig. 11* in series to oppose, and *Fig. 12* in parallel, each being drawn for a frequency making $\omega = 1{,}300$.

An inspection of the diagrams shows that in every case, except where the coils are in series to oppose, which would never be practicable because there is then no magnetization developed, the reactance is many times larger than the resistance of the coil. In the cases when they are in series or in parallel it is 22·75 times as much, and for the single coil 11·375.

When the receiver is used with reversing currents, such as are employed in the Wheatstone system, or with alternating currents, the impedance is the important element, and the value of the resistance makes very little difference, provided it bears so small a ratio to the impedance. If the coils of the

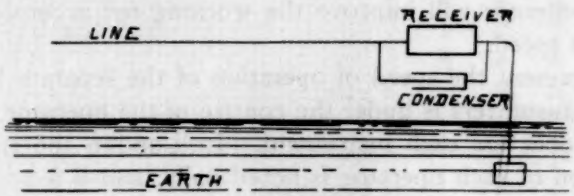


FIG. 13.

Wheatstone receiver are increased to 400 ohms, for instance, instead of being 200 ohms as at present, the impedance would only be increased about 13 ohms or 3½ tenths of 1 per cent.

It is found in practice, as above mentioned, that better results are obtained by the use of condensers, as indicated in *Fig. 3*. Instead of shunting the condenser directly around the receiver, however, a large resistance is first inserted in series between the receiver and the line and then the condenser shunted around this resistance. This inserted resistance is often larger than the impedance of the receiver. The reason for this particular arrangement of circuits seems to be that the waves have different lengths and the square-topped wave of electromotive force is used.

When the synchronograph was used with the Wheatstone receiver this resistance with its shunted condenser was removed

from the line and the condenser shunted directly around the receiver, as seen in *Fig. 13*.

The receiver and condenser thus form a resonant circuit, and by properly choosing the condenser it is possible to increase the receiver current materially, making it larger than the line current. This is the benefit of using a condenser, but the capacity for the best effect should vary with the frequency of alternation. By knowing the inductance of the receiver and the frequency, the condenser capacity can be calculated by the formula

$$C = \frac{1}{L\omega^2},$$

where C denotes the capacity of the condenser, L the inductance of the receiver, and ω is 2π times the frequency. The value of the capacity for any frequency is not very critical, that is, a condenser will improve the working for a considerable range of speed.

At present the speed of operation of the separate Wheatstone transmitters is under the control of the operator, and is independent for each instrument. In London the speed of operation of each operator is noted daily, and if found to be below a certain required limit an explanation is required from the operator. With the use of the synchronograph it is practicable to operate a number of transmitters from the shaft of one alternator, and it may be so arranged that the speeds are fixed beyond the control of the operator.

THE SPEEDS OBTAINED BY THE WHEATSTONE SYSTEM.

The present perfection of the Wheatstone system is much superior to that obtained with the original instruments. This improvement is due to Mr. Preece, who has gradually increased the speed from one or two hundred to six hundred words per minute. The Wheatstone system has been in commercial operation for so long a period that the speed expected on any given line is accurately known, and may be represented closely by an equation of the form

$$K\,R\,W = \text{a constant},$$

where K denotes the total distributed capacity of the line, R the total resistance, and W the number of words per minute. This constant depends upon the kind of line used, and differs

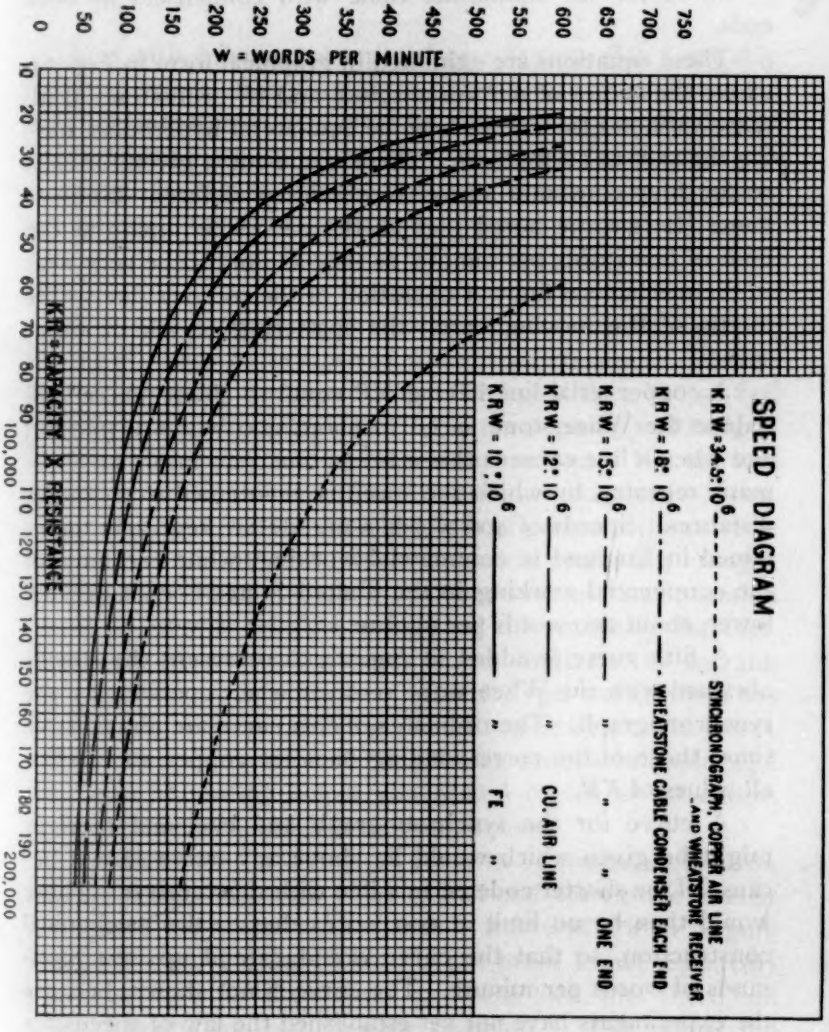

W = WORDS PER MINUTE
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
KR = CAPACITY X RESISTANCE
10 20 30 40 50 60 70 80 90 100,000 110 120 130 140 150 160 170 180 190 200,000
SPEED DIAGRAM
KRW = 34.5 · 10^6 ---------- SYNCHRONOGRAPH, COPPER AIR LINE AND WHEATSTONE RECEIVER
KRW = 18 · 10^6 —·—·—·— WHEATSTONE CABLE CONDENSER EACH END
KRW = 15 · 10^6 — — — " " ONE END
KRW = 12 · 10^6 ——— " CU. AIR LINE
KRW = 10 · 10^6 ——— " FE "

FIG. 14.

for iron and copper wire and for cables. The values of the constants determined by a series of experiments extending over a long period are

10×10^6 for ærial line of iron wire.

12×10^6 for ærial line of copper wire.

15×10^6 for submarine cable with condenser at one end.

18×10^6 for submarine cable with condensers at both ends.

These equations are exhibited in graphical form in *Fig. 14*, where the values of KR are abscissæ and W ordinates. With these variables the curves become equilateral hyperbolas, having the axes as asymptotes. There is one curve given for each of the four constants above, representing different kinds of lines. It is to be noted that all the curves terminate at the limit of 600 words per minute, as this is found to be very near to the mechanical limit of operation of the receiver due to the inertia of the moving parts, the spattering of ink or other causes.

A copper ærial line having KR equal to about 30,000 will reduce the Wheatstone speed to about 400 words a minute; and when a line exceeds this it is customary to insert an automatic repeater, by which the speed is maintained over longer distances. Speeds of 400 words a minute are regularly maintained in England in commercial working, while the limit of the commercial working in the United States is considerably lower, about 200 words per minute.

A fifth curve is added in *Fig. 14* to represent the speeds obtained with the Wheatstone receiver when operated by the synchronograph. The ordinates of this curve are about three times those of the corresponding ones for copper air line for all values of KR.

A curve for the synchronograph and chemical receiver might be given which would lie above any curve shown because of the shorter code permissible with this receiver. There would then be no limit at 600 words due to the mechanical construction, so that the curve would extend up into thousands of words per minute. The curve is not shown, because the experiments have not yet established the law of speeds for this combination of instruments.

[*To be concluded.*]

The SEVERY IMPRESSION PROCESS.

By Melvin L. Severy, Boston, Mass.,
Member of the Institute.

It is with a feeling of especial gratification that I am able to bring before an institution so imbued with the spirit of its founder, a matter which, were he here to-night, could hardly fail to interest him, so intimately does it seem to bear upon an industrial art which touched him very closely. As his representatives, I take great pleasure in describing to you a new method of printing, known as "The Severy Impression Process."

Historically speaking, it is but yesterday that the Leibnitz theory of innate ideas enjoyed widespread credence. To-day, happily, we have mostly outgrown this hypothesis, but we find something akin to it still surviving in the popular, and I regret to say, legal, view of the genesis of inventions. We are told about the relation of invention to intuition—how a new inventive idea is, as it were, a detached flash of genius without traceable origin, and other vague metaphysical means are brought to bear upon us in the attempt to convince us that invention bears no especial relation to logic or the reasoning faculties. This view of the matter seems to be about worthy to rank with the Platonic hypothesis of an archetypal world which has for so many centuries stifled genius in academic art. In briefly explaining the evolution of the printing process in question, I shall also be putting before you what I regard as the almost invariable method which invention pursues.

I had invented a biological game to be played with cards, each of which had a cut of an animal and descriptive matter. This game was placed in the hands of a Boston printer to publish, and when I came to correct the proof I was repeatedly asked to wait, for the reason, as I was told, that there had been difficulty in "bringing the form up." This phrase did not convey to my lay mind any definite idea, and on one occasion, when I was told that the delay was caused by inability to "make it ready," I asked, in despair: "What do you mean by

'make it ready?' " "Come out and see," was the laconic reply, and I was led into the press-room. I found there imperfectly printed portions of my game, with map-like marks in blue pencil, and upon these cards men were diligently pasting tissue paper, which they cut to form very carefully with a knife. This, I was told, was "make-ready," and it was my first acquaintance with the term. It was explained to me that every plate or type-form was uneven, some portions being higher than others, and this pasting on of paper was for the purpose of opposing on the tympan sheet (which is to say, under the sheet of paper to be printed upon) a valley to every mountain in the type-form or plate, and *vice versa*. I learned later upon inquiry that this "make-ready," as it was called, represented upon the average more than 50 per cent. of the total cost of press-work. It was an entirely novel experience to me, and I remarked to the printer then and there that there ought to be a better way of doing that, and I believed I could discover one. He replied that he would rather have a substitute for make-ready than any printing business in the world, but that efforts had been for many years made in that direction only to fail in every case.

Thus stimulated, I set to work. The first thought that occurred to me after some weeks of study was along the line of a pneumatic, or, still better, a hydrostatic cushion of peculiar construction. This, I reasoned, would give an equality of pressure all over a plate or form, and this pressure could be regulated to a nicety by a specially devised diaphragm and adjustable spring. Several hundreds of dollars were spent upon devices of this character, which were put upon a job press and tried. The result of these tests was the justification of the theory of equality of pressure, but the introduction of another factor not counted upon. It was found that when a portion of the plate was pressed into the cushion, the result was that the cushion, by the displacement of its contents, was forced down into all the unsupported or low places of the form; in short, that the printing of type had a tendency to force the diaphragm down between the type in a way to print in some cases the quads and furniture.

There seemed to be but one way of preventing this, and that was by using furniture and quads as high as the type, and preventing their printing by keeping the ink off of them by what is technically known as a "frisket," which is a sheet of paper which comes over the form just before the ink rollers pass over it and which is cut away over such portions of the form as are to be inked and printed. The necessity of such a "frisket" presented in the mind of the printer who was assisting in the performance of the experiments a very great obstacle to the success of the process, so much so that he laid the matter before the head of a printers' supply house. This gentleman said, in effect: "If you can do away with make-ready, don't be afraid of either type-high furniture or the necessity of a frisket, for such is the trouble and expense of make-ready that printers will gladly accept your process in spite of such drawbacks." This was reassuring, but it did not tell us how we were to use a frisket for the middle of a totally inclosed area, as, for example, a column of matter with a rule around it. What mechanician is there who has not at some time or other had a similar desire to connect one part of a machine with another across a line cut by a moving portion of his mechanism? Clearly the frisket in such cases, and they were very numerous, had to be abandoned, and it was, therefore, apparent that the pneumatic or hydrostatic cushion was not a satisfactory substitute for make-ready. It fulfilled its promise of equal pressure, but in doing what was expected of it at *one* portion of its area, it was made to do something else at *another* portion, which was not at all desired.

A great scientist has said that one often learns more from the experiment which fails than from the one which succeeds, and this was to some extent true in this case. I learned from this failure the requisites of proper printing, viz.: equal pressure per unit of area, which I approximately got in the hydrostatic cushion, and *independency of action*, which I conspicuously did *not* get, and the failure in the attainment of which rendered the results unsatisfactory.

How then to get this independency of action. That was the desideratum, and was arrived at by the following reason-

ing. If I thought I could get columns of molecules which would be obliging enough to yield longitudinally without affecting their juxtaposed neighbors, I should have what I want. Fluids could be made to yield readily, but not independently. If I couldn't get cake, I reasoned, I must take smelts, and as molecules wouldn't oblige me as I could have wished, I thought that pins with a spiral spring around each of them and capable of reciprocating in a backing would be the nearest approach to what was wanted. A second's consideration of this showed that it would be too coarse in arrangement, and too expensive in construction to meet the demands. The springs would be in the way and prevent the pins from being put close enough together.

The next step of reasoning was to discard the springs, make the pins themselves springs and set them closely together in a backing. The invention was beginning to crystallize. I had a bristle brush made of special design and did very creditable work with it. One very gratifying thing was sure, it was entirely independent in action in its various areas, for no one bristle had any possible means of knowing what another one was doing. Then arose the question of durability and a minor question of the uncertainty of the direction in which straight bristles would bend when pressed endwise. These questions were met by substituting for the bristle a tempered steel wire on the one hand, and upon the other giving to this wire a very slight curve to determine the direction of its flexure when pressed. All this was not arrived at in the time it takes to tell it. Much experimentation was necessary to determine the exact bend of the wire, the angle, the number of wires to the square inch, the size and temper of the same. Machinery had to be imported from England, taken down and altered over to weave this fabric, and other machines had to be devised to test it for wear and for its resistance to pressure. It should not for a moment be thought that this fabric, or any particular fabric, was the cardinal point of the invention, for such is not the case. It is the *multiplicity of independently yielding points, however arranged or of whatsoever material constructed*, that is the real essence of the invention. Tapering bristles, whether

of *rubber, fibre or hair, wire points,* howsoever arranged; in fact, all things having many independently yielding points, come easily within the scope of the invention. Each point of this fabric, and as at present constructed there are from 700 to 900 in each square inch, may be likened to a separate, automatically adjustable little platen, bent upon finding a portion of the plate, whether it be high or low, and pressing it with a definite pressure.

This brings us to a peculiarity of the fabric as at present constructed, which might easily be overlooked. It is this: The wires are slightly bent so that they may not "bunch" when they are flexed, and this bend is made *very slight,* so that each wire may give its greatest resistance when *first pressed.* In this way it will be seen that increased depression into the fabric *does not give increased impression,* or to put it another way, the high portion of the plate which touches the fabric first and is pressed farthest into it, does not encounter from the wires any greater resistance than the lower portions, for the reason that each wire gives its *greatest* resistance when *first pressed,* and then merely gets out of the way to allow the low places to come up. This fact is of the greatest moment in half-tone work, where a variety of pressures so mar the intended result that the plate is entirely at the mercy of the printer.

In the process under consideration this is not so, the individuality of the printer being entirely eliminated in all except the matter of inking, and the personality of the original artist mechanically recorded upon the paper as it is upon the half-tone plate. A few words will make this point clear: A half-tone plate is made by photographing an object through a screen, with the result that the light is diffracted in a way to leave the plate when etched composed of dots equidistant upon centers, but of every conceivable size, from a pin-point-area to large dots, practically coalescing with their neighbors to form a continuous solid. There is nothing else in the picture but these dots, and it will readily be seen, therefore, that justness of gradation of light and shade depends absolutely upon reproducing each of these dots of *just the size intended.*

The moment a sheet of tissue make-ready is placed over a section of a picture, the tendency is to give that part more pressure than other parts, and its dots are driven somewhat into the coated paper, and are materially enlarged, thus destroying all relativity of values intended by the original artist. It is in this way that a Bouguereau finds modeling in half-tone reproductions of his work taken from the originals which makes his artistic soul mutter anathemas deep, if not loud. Where is the subtlety of his carnations? Where the wonderful delicacy of his fugitive tones? Where the shimmering texture of breathing flesh? Where the marvelous consistency of his lighting that makes all parts of his work hang together like a string of pearls? It is gone, and there is little left but brutality, woodenness, false gradations, bad anatomy and a general pot-pourri of light and shade; and all this is brought about by nothing more nor less than altering, by variety of pressure, the sizes of these little insignificant dots. I do not mean to say that the results are always as bad as this, but when they are not it is due either to accident, or to the fact that the man who makes the cut ready is himself sufficiently versed in art and anatomy to know what is wanted.

Printers are wont to take the attitude that they are *themselves* the artists, and the real makers of the cut, but this hardly makes their position less deplorable, since what the *public wants* is the *personality* of the artist who creates the *original.* The business of the printer should be to suppress his personality and publish that of the artist, and this would not of necessity be accomplished were he always, what he almost never is, a great artist himself. How, think you, would Munkacsy relish having his work made ready by a Fuller who would insist that every one of his brilliant, firm tones should be viewed as through a mist? Set Corot to making ready Doré, and what would be the result?

The process we are considering mechanically justifies the plate, the plate mechanically justifies the picture from which it was photographed, and the artist's personality reaches the public pure and undefiled. The printer making ready by the old process is not to be blamed for all the shortcomings inher-

ing in the results. The chances are a hundred to one that he has never seen the original. Everything must be done empirically. Having decided in his own judgment how light the cheek of a figure should be, he has not in the least determined the degree of light that should be given to an arm. Every *feature* of a picture is *separately at his mercy*, and even if his taste be perfect, the mechanical difficulty of correlating all the features into just relations with each other is, to say the least, very considerable. By the new process the pressman finds a portion of the plate which has been burnished, and he knows that this part is to be printed in full color. He adjusts his ink and his pressure so as to get the color full on this one portion, and then *every other portion must* be right, even without the trouble of his looking at it, since the new process, with its equality of pressure, never meddles with gradations of tone. In short, it prints every dot in a half-tone of the exact size intended, never pressing the plate hard enough to drive the dots into the paper and so enlarge their impression.

What has been said about the justification of gradations in half-tones is, of course, equally true in type and all other grades of work. If the inking be properly done, the new fabric is sure to print type with that evenness of color which is by the old process so difficult to get.

Another very radical departure of the new process is in the matter of wear of type and plates. As at present constructed, presses are capable of rock-crusher pressure. The press upon which this fabric is shown has at its side-arms a crushing strength of over 150 tons, and its maker says he will warrant it to work steadily with 45 tons pressure inside the chase. Let us consider what this means to type and plates. Here, we will say, is a form of uneven type. A single type stands higher than the rest, and so invites the entire 45 tons pressure, since nothing else can be reached until this type is broken down or longitudinally compressed. Forty-five tons upon a single type! Now consider what would happen by the new process. The fabric which you will see to-night has a resistance of 112 pounds to the square inch. Suppose the high type to be a large one of ⅛-inch printing surface. In the former case 45

tons are brought upon it, if not previously crushed; in the latter case only the strength of those wires opposite to it, and, as it is ⅛ inch square, and the fabric has a resistance of 112 pounds per square inch, it would have to stand less than 2 pounds pressure instead of 45 tons. The ratio of strain is that of less than 32 ounces to 45 tons! Is it any wonder that type seem nominally indestructible by the new process, when you consider that they can never be pressed anywhere near the point at which the molecules of their metal flow.

A test made to illustrate the relative wear of plates by the old and new process showed the following results: Fifteen sets of plates were broken down in printing an edition by the old process, while a larger edition was done by the new process upon a single set of plates, the work being of very much higher grade, and the plates were reported in good condition at the end of the run.

This increased wear will readily be seen in the case of half-tone plates by brief reference to figures. A plate made from a screen having 150 lines to the inch gives 22,500 dots to each square inch of the plate. Now since the new fabric has, roughly speaking, 800 wires to the inch, it will be seen that before the plate can be injured each wire must press 28 dots to such an extent that their metal will flow, and as 800 wires exert but 112 pounds, the maximum pressure that any dot can have is 112 divided by 800 divided by 28, or about five thousandths of a pound, which, I think, you will admit reduces the fear of injury to an absurdity; while by the old process a single dot, if it happened to be much higher than its fellows, might get the whole effective pressure of the press.

What I have said about pressure has its correlative, of course, in power with the additional fact that, since each little wire is a spring, just so much power as a job-press consumes when its jaws bite the fabric in coming together is given back to the press when the jaws separate, barring infinitesimal losses by heat and friction, which need not be considered practically. The power, therefore, necessary to run a job-press is only such as would be required to do the inking, since that requires more power than the impression would consume.

It will readily be seen that this wire fabric may be made of any desired resistance, closeness of setting, size or bend of wire. That now in use is the result of months of experimentation and is intended to have pressure enough to do the work, and yet *not* enough to even approach the danger point of type or plate resistance. There are but two things to be done in printing a plate after it is upon the press. (1) Put the ink on properly. With this the new process has nothing to do. (2) Take this ink off measurably clean by pressing a paper against the inked surface. This the fabric in question is designed to do. I am aware that printers often claim that they have to resort to a great variety of pressure to "bring out" a cut properly, and I cannot take time at present to advert to this any further than to say that if the cut is well made this position is utterly untenable in the way in which it is usually stated. Pressure should be sensibly constant per unit of area. Barring air resistance, it takes no more pressure to print period-area, when it stands in the middle of a solid and as a part thereof, than it does when it stands alone and unsupported. Solids require more pressure simply because there are more units of area.

It may not be amiss to give a moment to statistics upon make-ready. In a paper read by W. B. Conkey, before the United Typothetæ of America, on September 9, 1896 (see *American Bookmaker* for October, 1896), the records of two press-rooms are given, the first containing four job presses and nine cylinders, and the second containing twenty-two cylinders. In the first case the make-ready occupied more than 60 per cent. of the total working during 300 working days. In the second, the make-ready occupied more than 57 per cent. of the total working time during a record of 103 working days. If the make-ready for conservative figures be put at 25 to 35 per cent. of the total working time, its aggregate cost will amount to a sum of very round proportions. With the cost of printing in the United States at $275,000,000 per annum, a process of abolishing make-ready and thereby saving more than one-fourth of the total cost of press work, should result in a very material advantage to the public. Add to this the

ease with which the fabric may be adapted to all presses, its nominal indestructibility, and the fact that it renders presses all but totally immune from accident, since loose type, or wadded paper, or similar obstructions will not, where they may be used, cause damage to the press, and its varied qualifications may be appreciated.

The ordinary layman has little conception of the great accuracy of adjustment necessary in the proper making ready of a form. Differences of a hundreth of an inch are overcome with comparative ease, it being the last ten thousandth of an inch that makes the trouble. The paper and the plate must be made to fit, not merely from the standpoint of the blacksmith, but rather that of an optician. As well might the paper be a thousand miles away from the ink as a thousandth of an inch—it either touches or it doesn't. The task of making this perfect fit of the paper to the uneven plate surface, of superimposing carefully-cut tissue paper, and even skiving its edges, is one that represents great labor, the highest skill, and is even then so uncertain a factor that the printer, unable to correctly estimate in advance, loses often all the profits calculated upon in figuring a job in this one under-estimated item of make-ready.

[At the close of his paper, the speaker made a practical demonstration of his process, which elicited considerable discussion. The meeting passed a vote of thanks to Mr. Severy for his interesting paper, and the subject was, by vote, referred to the Committee on Science and the Arts for investigation, and report thereon.]

THE SPECIFIC HEAT OF ANHYDROUS LIQUID AMMONIA.*

BY

LOUIS A. ELLEAU, M.E., NEW YORK,

AND

WILLIAM D. ENNIS, M.E., LONG BRANCH, N. J.

INTRODUCTORY.

The commercial product known as ammonia consists of a solution of ammonia gas in water, in strengths varying up to about 50 per cent. The anhydrous liquefied gas, a very different article, has until recently been a chemical curiosity. Owing to the rapid development of ice-making and refrigerating apparatus in the last few years, however, pure liquid ammonia has become well known to engineers, and has been the subject of much investigation.

This substance is manufactured by subjecting the gas to pressure at a low temperature. It is a colorless liquid, having a specific gravity of about ·62, boiling at — 33° C. (— 27° F.), at atmospheric pressure, giving off the suffocating vapor of ammonia. Owing to this low temperature of ebullition, the exposed liquid absorbs heat from surrounding bodies with great rapidity, a thick layer of congealed moisture settling on vessels containing it. It is sometimes frozen by the intense cold produced in evaporation. It is exceedingly dangerous to handle, producing ulcers on the skin, and even the vapor causes a painful burn. A single drop suffices to destroy the eyesight. It can be kept safely only in a strong cylinder, as its pressure at an ordinary summer day's temperature may rise as high as 200 pounds per square inch.

It has now been made practicable to reduce the amount of moisture in the liquid to an exceedingly small quantity, ordinarily to less than one-tenth of one per cent. Liquid ammonia is thus as pure a product as can be found among com-

* This paper was written as a thesis for the degree of Mechanical Engineer, at the Stevens Institute of Technology.

mercial chemicals, the other impurities, such as oils, etc., occurring in still more minute quantities. The manufacturers state its composition to be at least 99·9 per cent. NH_3.

HISTORY.

Various properties of this interesting substance have been made the subjects of experimental research by Regnault, Zeuner, Von Strombeck, Jacobus, Ludeking, Starr, and others. The heat of vaporization, specific gravity, density of the gas, specific heat of the gas, etc., are all more or less accurately known. The specific heat of anhydrous liquid ammonia, however, is a constant whose value has never been satisfactorily determined. For the last thirty years definite knowledge upon this point has been of interest and of some importance.

It is stated by Prof. De Volson Wood* that "certain properties of ammonia have been determined by Regnault, but his determination of the latent heat of vaporization and the specific heat of liquefied ammonia were lost during the reign of the Commune in 1870."

Ludeking and Starr† also assert that "the specific heat of liquid ammonia has never been satisfactorily determined experimentally, if we except the work of Regnault. His results, however, were unfortunately lost during the Paris Commune."

It is certain that much of the data and many of the calculations of this illustrious experimenter were lost during the siege of Paris and the demolition which succeeded it. M. Debray, speaking in eulogy of his colleague before the French Academy,‡ says: *"La main brutale d'un soldat ennemi avait detruit, dans son laboratoire de Sevres, les nombreux et precieux instruments de mesure qui lui avaient coute tant de labeurs et sans lesquels toute recherche lui devenait impossible."*

Whether or not a determination of this quantity was ever made by Regnault, he used for the specific heat the value ·799,¶

* *Thermodynamics*, p. 325. One of Regnault's latent heat determinations has, however, been found.

† *Am. Jour. Science*, III, **45**, 200.

‡ *Comptes Rendus*, **86**, 134.

¶ *Am. Jour. Science, loc. cit.* See also *Jour. Frank. Inst.*, **130**, 472.

assuming the specific gravity to be ·76.* The authority of this scientist's results is seldom to be questioned; but in the absence of his data and of a positive statement as to his having ever accomplished the work in question, various other experimenters have attempted to solve the problem.

The first recorded tests are those of Dr. Hans Von Strombeck, the records of which may be found in the *Journal of the Franklin Institute*, December, 1890, p. 467, *et seq.* He heated the ammonia, which was contained in a closed steel cylinder, in the vapor of boiling methyl alcohol circulating in a jacketed drum. The range of temperature of the liquid was from about 62° C. to 31° C., the maximum pressure in the drum being, then, about 400 pounds per square inch.

Dr. Von Strombeck's work gives evidence of great care and thoroughness; his result is not far from that obtained from theory by Zeuner.

The value given is 1·22876.

A later experimental research has been made by C. Ludeking, Ph.D., and John E. Starr, C.E., and is published in the *American Journal of Science.*† The same form of apparatus—that of Regnault—was used as in the tests of Von Strombeck. The vapor of carbon disulphide was used to heat the ammonia, giving a much less excessive pressure than in the previous determination. The ratio of the masses of steel and ammonia was also better, being 70·998 to 10·01, or 7·1 to 1. The specific gravity of the liquid, however, is given as ·656, which appears to be an error. D'Andreff's formula,‡ generally accepted, and by which Von Strombeck obtained his specific gravities, gives as the temperature of the air, 25° ·4 C., at which temperature, presumably, the cubic contents of the holder were ascertained,

$$·6364 - ·0014\ t = ·6008,$$

while for the initial and final temperatures of the ammonia the value is even less than that given above.

The reported result is ·8857.

* *An. de Chim. et de Phys.*, IV, **24**, 418.
† *Am. Jour. Science*, III, **45**, 200.
‡ *Trans. A. S. M. E.*, **10**, 641.

The high reputation of both Ludeking and Starr as experimentalists caused their disagreement with Von Strombeck to leave the result, if possible, more than ever in doubt. In addition to the above values obtained by experiment, various theorists have analyzed the subject from general assumptions.

Prof. De Volson Wood calculates the value in the following way:

Assume the volume mM, *Fig. 1*, of the pound of liquid to be constant at all pressures, and let $M\,D$ be the absolute pressure at the absolute temperature τ; and let $B\,C\,S$ be the curve of saturated vapor, $D\,H$, $A\,G$, $B\,F$, $I\,K$, adiabatics. Let the vapor be expanded from D at the pressure p and the temperature τ until it is all evaporated at C, thence compressed adiab-

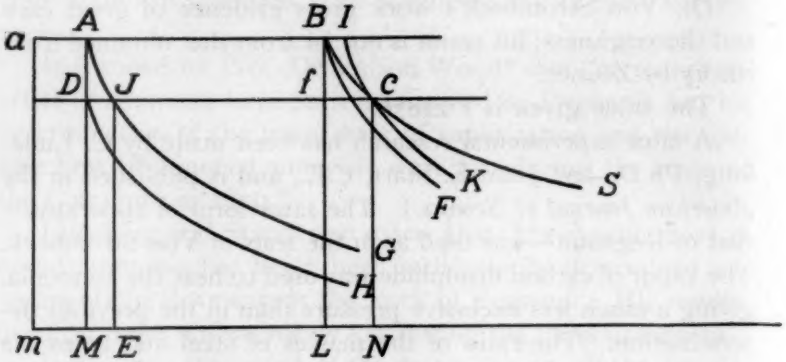


FIG. 1.

atically to I, thence at constant pressure to A, where it is liquefied, thence by abstraction of heat let the pressure be reduced to D; then,

$$H\,D\,A\,G + G\,A\,I\,K = H\,D\,C\,K + D\,C\,I\,A \qquad (1)$$

Let the temperature of $A\,B$ be $\tau + \delta\,\tau$, and of I, $\tau + \delta\,\tau'$, for the vapor from B to I will be superheated, its temperature increasing with increase of volume; then if c be the specific heat of the liquid,

$$H\,D\,A\,G = J\,C\,\delta\,\tau \qquad H\,D\,C\,K = J\,h_e$$

$$D\,C\,I\,A = v\,\delta\,p \qquad G\,A\,I\,K = G\,A\,B\,F + F\,B\,I\,K$$

$$h_e - h'_e = -\,\delta\,h_e \qquad G\,A\,I\,K = J\,h'_e + J\,K\,p\,(\delta\,\tau' - \delta\,\tau)$$

$$\therefore c = \frac{v}{J} \cdot \frac{\delta\,p}{\delta\,\tau} - \frac{\delta\,h_e}{\delta\,\tau} - K\,p\left(\frac{\delta\,\tau'}{\delta\,\tau} - 1\right) \qquad (2)$$

From the formula for the latent heat of evaporation,

$$h_e = 555{\cdot}5 - 0{\cdot}613\ T - 0{\cdot}000219\ T^2,$$

$$-\frac{\delta h_e}{\delta \tau} = 0{\cdot}6130 + 0{\cdot}000438\,T.$$

From Rankine's formula* for the relation between pressure and temperature of a saturated vapor, representing the results of Regnault's experiments,† we have,

$$com.\ log.\ p = A - \frac{B}{\tau} - \frac{C}{\tau^2} \tag{3}$$

The value of C in this case is very small. Substituting the proper constants for ammonia,‡ we have, very nearly,

$$com.\ log.\ p = 8{\cdot}4079 - \frac{2196}{\tau} \tag{4}$$

$$\frac{\delta p}{2{\cdot}302585\ p} = -\frac{2196\,\delta \tau}{\tau^2} \tag{5}$$

$$\frac{v\,\delta p}{J\,\delta \tau} = 6{\cdot}49922\ \frac{p\,v}{\tau^2} \tag{6}$$

From

$$p\,v = a\,\tau - \frac{b}{v^n}$$

the general equation of vapors, and

$$\frac{\tau}{\tau_2} = \left(\frac{v_2}{v}\right)^{\gamma}$$

the law of adiabatic expansion, we have, making the proper substitutions for ammonia gas,

$$p = 91\ \frac{\tau_2}{v_2}\left(\frac{\tau}{\tau_2}\right)^{4{\cdot}364} - \frac{16920}{v_2^{1{\cdot}97}}\left(\frac{\tau}{\tau_2}\right)^{6{\cdot}6274} \tag{7}$$

Differentiating with respect to p and τ, changing $\delta\,\tau$ to $\delta\,\tau'$, dropping all subscripts, and substituting the value of $\delta\,p$ from (6), we have, by substitution in (2),

$$c = 1{\cdot}12136 + 0{\cdot}000438\ T + \frac{p\,v}{\tau^2}\left[6{\cdot}49922 - \frac{0{\cdot}50836 \times 2{\cdot}3026 \times 2196}{397{\cdot}13 - \frac{112135}{\tau\,v^{0{\cdot}97}}}\right]$$

* *Edin. New Phil. Jour.*, **47**, 235, *et seq.* *Phil. Mag.*, 1854.

† *Mem. de l'Acad. des Sci.*, 1847. *Comptes Rendus*, 1854.

‡ *Rel. des Exp.*, Regnault, **2**, 598-607.

As this investigation depends upon a comparatively small range of volumes, and upon assumptions with regard to the forms of the functions in some of the assumed equations, it may not be very reliable for a large range of temperatures. For $\tau = 426°{\cdot}6$, $T = -34°$ F., $p = 1823{\cdot}7$ pounds per square foot, $v = 20{\cdot}7985$, we have,

$$c = 1{\cdot}093 \text{ (at } -34° \text{ F., or } -38° \text{ C.)}.$$

A result obtained from such theoretical and empirical considerations will, at best, give only approximate results, and will be used only in case of necessity. It may never be substituted for results obtained by direct experiment, if the accuracy of the experiment is assured. The very fact that the above analysis gives a value between the two extreme experimental figures speaks in its favor. It also shows what may be considered certain, that the quantity varies with the temperature.

M. Ledoux deduces from the total heat and the latent heat an empirical expression of the form

$$A' + B't + C't^2,$$

the constants of which are calculated by means of three values taken at the extremities and middle of the thermometric scale, and previously determined by means of thermodynamic equations for the above properties. This gives for the specific heat of liquid ammonia,

$$c = 1{\cdot}0058 + {\cdot}003658\, t°\text{C.},$$

which approximately agrees with Prof. Wood's analysis.

We thus have five values for the unknown quantity, viz.:

	Value.	Authority.	Temperature.
(1)	1·22876	Von Strombeck.	45° C.
(2)	1·093	Wood.	−38° C.
(3)	1·043	Ledoux.	10° C.
(4)	0·8857	Ludeking and Starr.	40° C.
(5)	0·799	Regnault.	———

There is no agreement, as the variation is greater than could be accounted for by the variation of the temperatures of the experiments. A new determination is necessary to settle

the matter. Such a new determination the writers have attempted to make.*

In the preparations for our work, the methods and apparatus of all previous experimenters of whose work we were informed were carefully studied, including those of Regnault, Von Strombeck, Jacobus, Starr, and Ludeking.

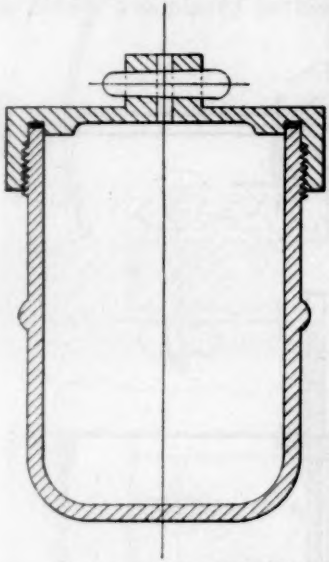
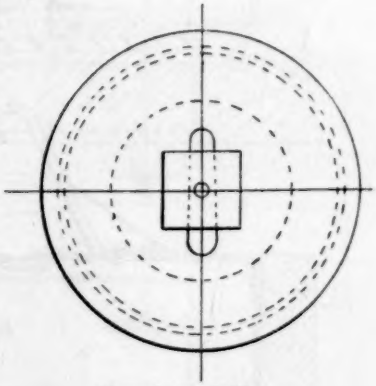


FIG. 2.—Ammonia holder.



Top view of Fig. 2.

***Note.—The ammonia tables given by various authorities do not agree with any great exactness. We have used the tables of Professor Wood, comparing them with those of Zeuner, and rejecting all unconfirmed values which would appreciably vary the result.**

The deductions of Ledoux, given above, are explained in detail in his "Machines à Froid," a translation of which, by Professors Denton, Jacobus and Riesenberger, has been published in Van Nostrand's Science Series.

The calculation of Professor Wood's value for the specific heat is given in his "Thermodynamics," edition of 1895, p. 335.

A confirmation of the theoretical conclusions of Ledoux has been brought forward by Prof. J. E. Denton (Trans. A. S. M. E., 13, 522). In a refrigerating test, the following values for the latent heat were found, at temperatures corresponding to those given by Ledoux:

Ledoux gives (1) 583·1 (2) 528·1.

Denton finds (1) 581·2 (2) 521·0.

It is probably less than 580 B. T. U. See p. 389, Wood's *Thermodynamics*, and foot-note.

EXPERIMENTAL RESEARCH.

The apparatus used was designed entirely by the writers. and constructed under their personal direction. It consisted essentially of an ammonia holder suspended in a closed chamber surrounded by melting ice.

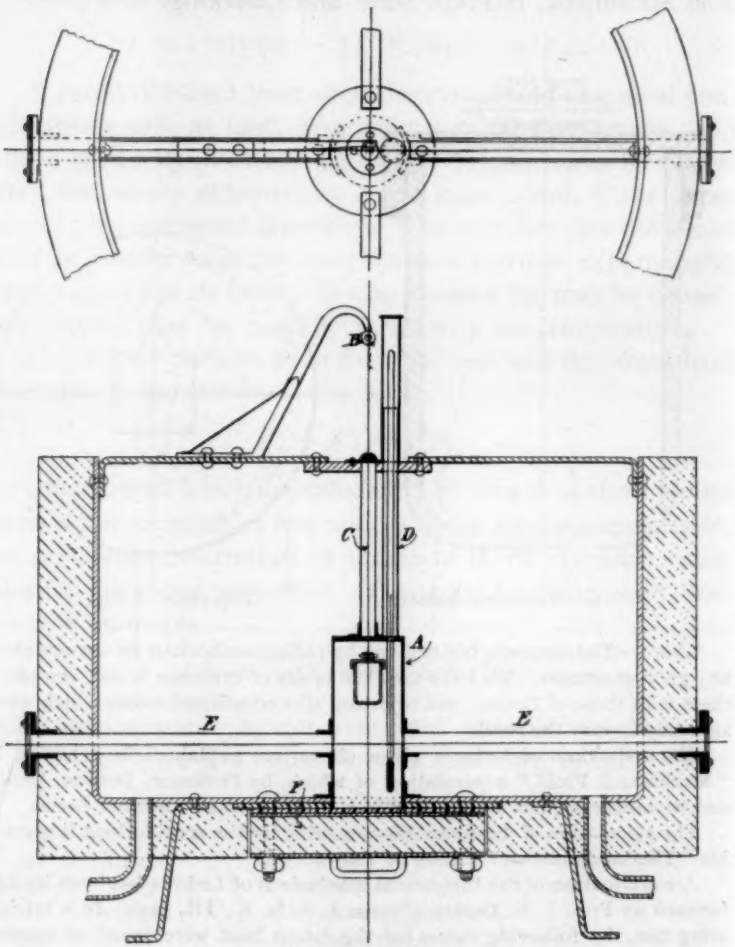


FIG. 3.—Cooler.

The ammonia holder, *Fig. 2*, was of soft steel, with an accurately ground lead washer for a bearing surface. It was turned from a solid bar, and was of a uniform thickness of $\frac{1}{16}$

inch. The thread on the cap was made so as to be screwed without using the wrench. The use of the pin through the cap will presently be shown. It was case-hardened, ground to fit the hole, and again hardened. The cooler, *Fig. 3*, was essentially an iron tank, in the bottom of which was inserted a copper box, *A*, brazed at all joints so as to be air and water-tight. The holder was placed in this box, hanging from the hook, *B*,

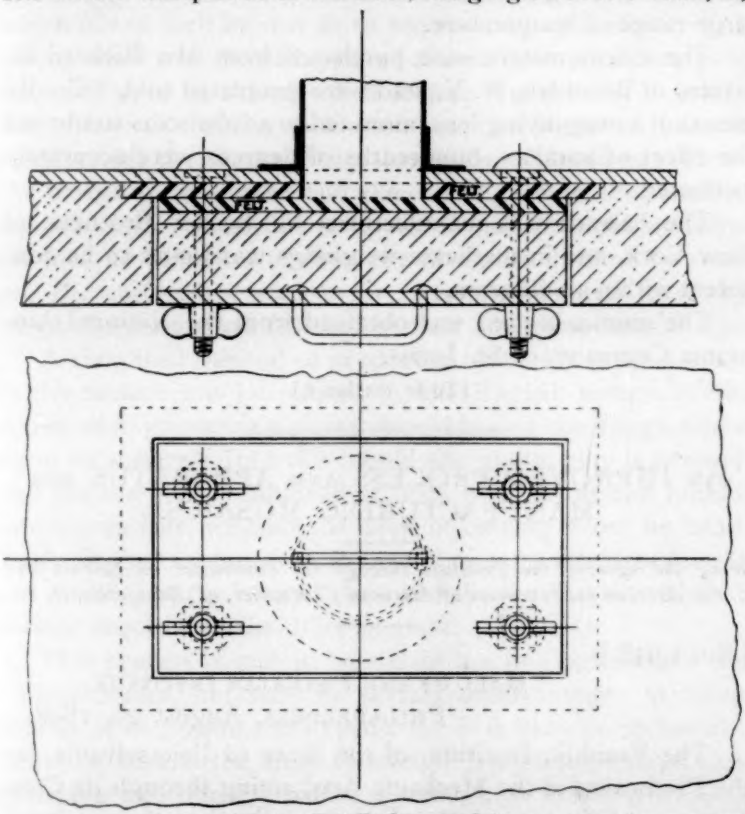


FIG. 4.—Detail of cover plate.

upon a thread which extended through the fine tube *C*. The thermometer for ascertaining the temperature of the cold chamber *A* was suspended in the brass tube *D*, and was read through the blackened sight tubes *E E* by means of a cathetometer telescope. A gas flame furnished the necessary illumination through these tubes.

Below the chamber *A* was a plate *F*, shown in detail in *Fig. 4*, which was at once air-tight and easily removable. The entire tank was coated with a 2-inch thickness of asbestos felt and canvas.

The calorimeter used was of the non-jacketed type, of copper, and had a total capacity of about 90 cubic centimeters. It was made as light as possible, in order to obtain a sufficiently large range of temperature.

The thermometers were purchased from Mr. Richard K. Green, of Brooklyn, N. Y., and were graduated to $\frac{1}{10}$° C. By means of a magnifying lens, mounted in a tube so as to obviate the effect of parallax, hundredths of degrees were accurately estimated.

The balance was manufactured by Becker Brothers, of New York, and in duplicate weighings was found to be consistent within a milligram.

The ammonia used was obtained from the National Ammonia Company, of St. Louis.

[*To be concluded.*]

An Improved Process and Apparatus for Manufacturing Mosaics.

Being the report of the Institute, through its Committee on Science and the Arts, on the invention of Herman C. Mueller, of Zanesville, O.

[No. 1,958.]

Hall of the Franklin Institute,
Philadelphia, August 26, 1898.

The Franklin Institute, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of "Mueller's Process of, and Apparatus for, Manufacturing Mosaics, etc.," finds as follows:

That the invention is the subject of Letters-patent of the United States, No. 537,703, dated April 16, 1895, granted to Herman C. Mueller, of Zanesville, O., and operated on the commercial scale by the Mosaic Tile Company, of that city.

For the proper understanding of the scope and character of this invention, it will be necessary to present some historical data in connection with the development of this branch of the arts.

The earliest specimens of the art that need be considered in this report are those known respectively as the Roman and Florentine mosaics, the characters and modes of producing which are so well known as to require no explanation. Following these well-defined types of mosaic decoration, came the encaustic tiles of the so-called Italian renaissance, in which the surface of the clay slab was carved or engraved in such manner that the lines and surfaces to be executed in color in the design were sunken and then filled in with the required colored clays. After this composition had acquired sufficient hardness to permit of cutting, the tiles were finished by shaving the surface to remove the excess of colored clays, by which the design was exposed in clear and sharp lines.

A simplified method of producing tiles with designs inlaid in the surface was introduced by the English potters. This consisted in preparing a plaster mould having the design raised upon its surface. Into this mould the plastic clay is pressed, and the tile is thus obtained at once with the design sunken into the surface, without the labor of carving it out by hand. To finish the tile, however, there still remains the same laborious inlaying of the colored clays and the shaving down of the surface required in the older method.

This process is said to be still in use in England and the United States, but has the several disadvantages of being tedious of execution and expensive. It is likewise technically defective, in that the large shrinkage of a plastic-formed clay in drying and burning makes it difficult to obtain a product sufficiently true for floor use, and this difficulty becomes well nigh insurmountable when several colors are inlaid in the same piece.

In 1840, Prosser, in England, invented the process of making tiles with clay-dust or flour, by compression. This is known as the "dry-press process," and has replaced the plastic clay process for unicolored tiles.

In 1852, Villeroy and Boch, of Mettlach, in Germany, invented a dry-press method for the inlaying of colored designs with clay-dust, thus obviating the difficulties inherent in the plastic clay methods, and substantially improving upon the dry-press method of Prosser. This process, which is widely practiced in the production of inlaid designs, like the Florentine mosaics and those of the inlaid encaustic tiles, is executed in the following manner:

A cloisonné, or compartment-frame, made of thin strips of metal bent to follow the outline of the design and the different colors and soldered together, serves, upon being set in the steel die in which the tiles are to be compressed, to divide it into compartments coincident with the design.

In these compartments of the frame, set in the die, the colored clays in the form of dust or flour are carefully filled. When all the clay is in place, the compartment-frame is carefully lifted out. The design now lies in the bottom of the die, in the form of a loose powder, but each color holds the other in its exact position. To give the tile the necessary body, a coarser backing clay is sifted upon the colored inlays, until the die is filled, when the whole is solidified by heavy pressure. Upon removal of the tile from the die and reversing it, the pattern will be found upon the surface, the colors penetrating, as a true mosaic of the Florentine type.

Economical in execution and technically satisfactory as this process has proven itself to be, it suffers from the limitation imposed upon larger and particularly original designing, in the great cost of the cloisonné or compartment-frames. Thus, the production of a two-color mosaic pattern, complete upon a single tile, requires five compartment-frames exactly conforming to the design, for one press. Each frame, for a moderately simple pattern, requires for its making three days' labor of a highly skilled mechanic, a minimum cost of from $45 to $50, hence, designing in this art has been practically restricted to damask or diaper patterns, with repetition of the individual figure not over 6 inches or a foot square.

Considerations of cost, therefore, practically, exclude the application of this method in the case of designs of an area

involving a larger number of different tiles, and would absolutely prohibit its use in the case of original designs, which are to be used once or twice only.

We now come to the process and apparatus of Mr. Mueller, which form the subject of this investigation. The process belongs in the class of the dry-press processes, and the inventor has a simple and ingenious mechanical means of making inlaid designs of various colored clays, reproducing the form and color of any original, which affords not only a radical solution of the problem of cost by which the pre-existing methods were handicapped, but also renders possible the making of a product having unique artistic characteristics, and which gives fair promise of greatly extending the field of indestructible polychromatic paving, flooring and interior and exterior mural decoration in modern architecture.

The basis of the Mueller invention consists in part of an improved method of distributing the colored clays to the compartments of the frames by sifting the same through specially prepared stencils of stiff paper, and in part of an improved "cell-frame" for holding the body of the pulverized clays distributed through these stencils. With the aid of this improved cell-frame and the paper stencils, through which the colored clays are sifted, any design or part of a design of large area, falling on a single tile, can be executed without the use of a special cloisonné or compartment-frame, which, because of its excessive cost, limited the utility of the older method above referred to.

The scope and character of the invention will appear very clearly from the first claim of the Mueller patent, to-wit:

"The improvement in the art of producing mosaics or ornamentally surfaced tiles or entablatures, consisting in dividing the mould-space by intersecting partition walls of uniform thickness into an aggregation of open cells; removing the partitions and allowing the cell contents to rest upon the bottom of the mould and acquire lateral support against each other; and, finally, by compression of the entire aggregate mass of earth, compressing the tile in the usual manner for the finishing operations, substantially as set forth."

To illustrate the great saving in the cost of reproducing an original design by his process, as compared with the most improved method previously known and used, the inventor submits the following comparison, the accuracy of which the investigating committee does not question.

"A panel 12 feet square, showing the crest of the Count of Chambord, was exhibited at the Paris Exposition in 1889, the compartment-frames for producing which, made at the factory of Boch Frères, in Maubege, cost 20,000 francs." * * *

"The preparation of the paper stencils for these designs would cost not to exceed $15, the stencils all being used with one and the same cell-frame, which is not more expensive to make than a single cloisonné, or compartment-frame, while the making of the numerous frames required for the design cost, as stated, $4,000. Furthermore, the making of these cloisonné or compartment-frames would require 1,800 working days of the service of a skilled mechanic, while the paper stencils for my system would only take the service of a girl for twenty working days."

"The thorough practicability of my process has been proven by its use on a manufacturing scale since the issue of the patent, in the works of the Mosaic Tile Company, at Zanesville, O., where works of very much greater dimensions than the one cited above have been executed, and that, too, for but a single application, although the process is essentially a multiplying one."

The mechanical details of the Mueller process will be clearly understood from the following description:

Stencils.—The design being made, it is cut into pieces, corresponding with the size of the tile to be made. As the tiles shrink in burning, the original design must be made accordingly on a larger scale. (This shrinkage amounts to about ½ inch to the foot). It is not necessary that the colors should be painted on the cartoon, an outline of the different colors will suffice.

With the aid of a punching machine, which transfers the design to the paper stencils to be cut, a stencil is made for every color that is to be inlaid in the tile.

Dies.—Tiles are pressed in steel dies, which are about 1½ inches deep and are open on both sides. (*Fig. 1.*)

Bottom Plate.—A bottom plate forms the foundation for the tile to be pressed, the die resting on it. (*Fig. 2.*)

This plate holds the metal mould on which the tiles are pressed. It must be very strong to withstand the pressure.

Top Plate or Plunger.—The top plate or plunger consists of a steel block, which enters the die and compresses the clay sifted in. It is also used to push the tile out, after it is pressed and after the bottom plate is removed. (*Fig.* 3.)

Cell-frame.—A cell-frame, consisting of metal strips described in what has preceded, is used to keep the colors to be sifted in in their places, according to the intended design.

Stencil Holder.—To give the paper stencils more stability,

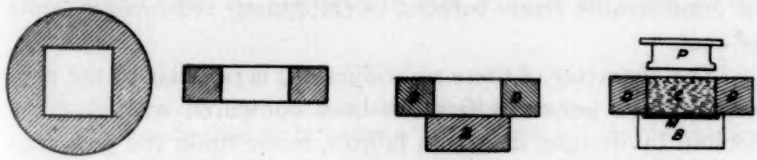


FIG. 1. FIG. 2. FIG. 3.

D, die; *B*, bottom plate; *P*, plunger; *C*, clay; *M*, metal mould.

and hold them firmly to the cell-frame while the colors are in, a metal or tin frame is used, which also protects the die from any color falling on it.

The stencil holder fits the die exactly and enters it to some extent.

The Pressing.—After the die is set on the bottom plate, the cell-frame is inserted, so that it rests on the bottom. This apparatus is passed to the first workman, who lays the stencil in the die and sifts the corresponding color in. This color (powdered colored clays) falls through the holes in the stencil into the small compartments of the cell-frame (which corresponds with the holes in the stencil). After the first color is sifted in, the stencil is withdrawn, the apparatus is passed to the next sifter, who repeats the performance with another color, and so on, until all the needful colors are sifted in and every compartment of the cell-frame is filled.

The cell-frame is then withdrawn and the inlaid mosaic is left lying on the bottom of the die. The backing material (powdered clay of coarser substance) is then sifted in until the die is filled. With a straight edge this clay is struck off and the plunger (top plate) is laid on the clay. The apparatus is shoved under the hydraulic press and the pressure is turned on (2,000 pounds to the square inch). After the tile is pressed and the pressure relieved, the apparatus is passed from under the press, the bottom plate is removed, the plunger is pushed further down and the tile drops from the die, ready to go to the drying-room, and thence to the kiln.

From the foregoing description of the Mueller invention, it will be apparent that it can be applied to the production of permanent floor and mural decorations from original designs of considerable sizes, without overstepping reasonable limits of cost.

The character of these reproductions is peculiar to the process, and its general effect has been compared with that exhibited by designs in woven fabrics, made upon the Jacquard loom. It is in fact adapting the principle of the Jacquard invention to the art of mosaic work.

The practicability of the process for work of considerable magnitude has already been demonstrated by the inventor, in the successful production of mural tablets, friezes, mosaic flooring, etc., and it would appear that for work on exteriors and interiors, that is to be seen at a considerable distance from the eye, the process promises to be particularly well adapted.

It will be premature to attempt, at this stage of the development of this ingenious process, to define the limits of its utility. The committee to which this invention was confided, is unanimous in the belief that the invention marks a distinct step in advance in the art to which it relates, and that it offers an admirable means of greatly extending the application of polychromatic decoration of a durable character and of considerable artistic excellence in architecture—something of which architecture of the present day is very much in need.

For these reasons, the Franklin Institute recommends the award of the John Scott Legacy Premium and Medal to the inventor, Herman C. Mueller, of Zanesville, O.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897, and approved by the Board of Directors of City Trusts.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
JAMES CHRISTIE,
Chairman of the
Committee on Science and the Arts.

THE ECONOMETER: A GAS BALANCE FOR INDICATING CONTINUOUSLY THE PROPORTION OF CARBONIC ACID GAS IN THE FLOW OF FURNACE GASES.

Being the report of the Institute, through its Committee on Science and the Arts, investigating the invention of Max Arndt, of Aix-la-Chapelle.

[No. 1,973.]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 1, 1897.

The Franklin Institute, of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Arndt's Econometer, reports as follows:

The sub-committee appointed to investigate the operation of an instrument for the measurement of carbonic acid gas (CO_2) escaping in the flow of the products of combustion from a steam-boiler furnace, have performed the duty assigned them, and beg to report that:

This instrument is known under trade name of Econometer, and is the invention of Max Arndt, of Aix-la-Chapelle, Germany, by whom it was patented in the United States, October 16, 1894.*

* See U. S. Patent, No. 527,397.

Through Mr. Joseph Wilckes, of New York City, the inventor's American representative, a request has been presented to this Institute for an examination into the merits of the instrument, for the purpose indicated above.

The apparatus consists of a balance beam, carrying at one end a gas vessel, provided with a neck open at the bottom; a gas delivery pipe projecting upward into this gas vessel being fixed and supported in it in such a way that upon the oscillation of the balance beam the gas vessel may move freely up and down without coming in contact with the upward projecting pipe through which the gas flows into the gas vessel.

The gas vessel is balanced by a compensating vessel suspended from the opposite end of the beam, also open at the bottom, and equivalent to the gas vessel in its capacity in conjunction with small weights placed on a pan under the compensating vessel, that the pointer of the beam shall move to zero on the scale when atmospheric air is drawn through the apparatus.

The gas vessel being open at the bottom, so that the pressure within it is always the same as that without, fluctuations of pressure and barometrical readings have not to be considered in the use of this apparatus, likewise fluctuations of temperature do not affect its action, because the gases passing slowly through the apparatus quickly take the temperature prevailing in the narrow gas passages.

The fluctuations which take place in the density of the gases round the fixed pipe in the gas vessel cause up-and-down motions in the latter vessel, which are shown by the pointer on the scale. This pointer is rigidly fixed to the beam so as to follow the movements of the gas balance; it oscillates in front of a divided plate or scale, indicating units of weight by the distance between its dividing lines, or these distances shall in conjunction with the pointer indicate a particular percentage volume of a particular kind of gas in a gaseous mixture. For example, the instrument placed at the disposal of this committee had divisions on its scale for indicating the percentage volume of carbonic acid gas, for the purpose of ascertaining

the percentage of such gas escaping in the products of combustion from a steam-boiler furnace.

Two tubular orifices are provided, one for the inlet, and the other for the outlet of gases, the former connecting by a flexible tube with the vertical fixed pipe in the gas vessel, and the latter by a flexible tube with the cup-shaped vessel situated below the gas vessel. The source of the gas supply is placed in communication with inlet leading to the gas vessel, and a suction apparatus of any suitable kind in communication with outlet from the cup vessel under the gas vessel. A portion of the air present in the casting is first drawn off, that is to say, the air is exhausted by suction to so much of a vacuum as corresponds to the strength of the suction at the cup vessel under the gas vessel. This rarefaction being obtained, the gas to be weighed passes into the gas vessel, filling it, and then out of this vessel into cup vessel below.

The gas balance is enclosed in a casing provided with a glass front for the purpose of observation; this casing is provided with an aperture closable by a plug, upon the removal of which the weights may be adjusted as required. Further, at the top of the casing, there is an aperture filled with cotton-wool for the gradual and continuous admission of atmospheric air thereto. The balance is, therefore, located in a nearly air-tight chamber, with its several parts so arranged that, when the gases to be weighed flow through a vessel forming part of the balance, it may operate without resistance and with greatest sensitiveness.

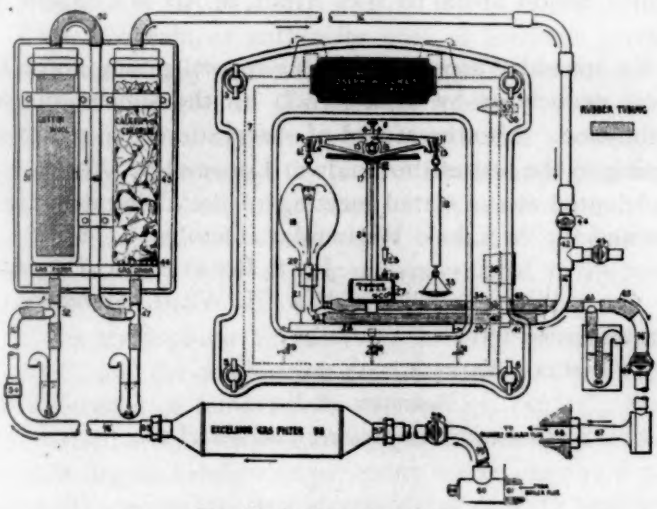
The determination of the percentage volume of a particular kind of gas contained in a gaseous mixture is only practicable by means of the apparatus when the specific gravity of the gas sought for is different from the specific gravities of the other gases preponderating in the gaseous mixture, but such other gases may be of like specific gravity among themselves. This, for instance, is the case with respect to the smoke gases of steam-generator furnaces, which gases are mainly made up of oxygen, nitrogen, carbonic oxide and carbonic acid. Of these, the first three are of nearly the same specific gravity, approxi-

mating that of atmospheric air = 1. On the other hand, the specific gravity of carbonic acid = 1·52, and is, therefore, about one-half heavier than atmospheric air, and a smoke-gas mixture must consequently be heavier the greater its contents of carbonic acid. With perfect combustion of the carbon contained in the fuel and with the air of combustion measured in a theoretically accurate manner, the carbonic acid of the smoke gases amounts to about 20 per cent. of the total volume, but it is less than this when the air of combustion is supplied in a larger quantity. If now the zero line of the scale has such a position that it coincides with the pointer when only atmospheric air is present in the gas vessel; if, further, the end line or division of the scale has such a position that it coincides with the pointer when atmospheric air mixed with carbonic acid to the extent of 20 per cent. of the total volume as determined by a chemical analysis, is drawn through the gas vessel; and if, further, the scale has twenty corresponding divisions, then the movement of the pointer from one division to another will correspond to the difference in the weight of the gaseous mixture in proportion to the percentage volume of carbonic acid; and accordingly, in the practical use of the apparatus, that is to say, when smoke gases are being conducted through the gas balance, the contents of carbonic acid, as indicated by the pointer in a sufficiently accurate manner for practical purposes, may at any time be read off from the scale direct. If, for instance, the pointer points to the division line marked 12 on the scale, this would indicate that the smoke gases drawn through the vessel contain 12 per cent. in volume of carbonic acid, that is to say, the volume of the latter would amount to 12 per cent. of the whole volume of the smoke-gas mixture.

If the smoke gases of a steam-generator furnace when passing to the chimney have a temperature of 270° C. (or 518° F.) and 12 per cent. of their total volume consists of carbonic acid, the loss of heat amounts only to about 15 per cent.; but if at the same temperature the carbonic acid contents amount, for example, to only 4 per cent. of the volume of the waste gases, this would show a loss of heat of about 45 per cent., due in a great measure to the heating of an excessive quantity of

air for the combustion of the fuel. Hence, it results that the gas balance herein described is of great importance as a controlling apparatus for steam generator and other furnaces and also for obtaining the specific gravity of other gaseous mixtures by direct weighing.

A practical test of this instrument was made by the investigating committee, at the Baldwin Locomotive Works in this city, with the results given in the annexed table. The boiler furnace from which the supply of gas was taken was one in which anthracite coal was used, the boiler was of the Babcock & Wilcox manufacture, and its furnace setting was in no re-



The Arndt "Econometer."

spect different from their ordinary practice. The gas analysis was by Prof. Harry F. Keller, Ph.D., of this city, each analysis was made immediately upon the withdrawal of the samples and at the place where the other tests were being conducted.

These comparative tests satisfied the investigating committee as to the substantial accuracy of this instrument. The recorded variations given in the annexed tables show discrepancies so trifling that, if the econometer were used in the management of steam-boiler furnace fires, no considerable loss would occur by reason of the difference between the

econometer reading and the chemical analysis. A saving in fuel would result because of a better and more intelligent management of fire and damper, allowing less surplus air to pass through the furnace than would ordinarily be the case.

The "Econometer" works continuously, and shows automatically the percentage of carbonic acid in the gases, thus enabling the fireman to see at all times the more or less favorable conditions of combustion.

The claims made for this instrument have, in the opinion of the investigating committe, been fully substantiated in its presence, and the Franklin Institute therefore awards the Elliott-Cresson Medal to Max Arndt, of Aix-la-Chapelle, Germany.

An appendix accompanies this report, giving some theoretical deductions by Max Arndt, on the subject of partial combustion. Also the record of observations and gas analysis relating to the test at the Baldwin Locomotive Works.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 6, 1897.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,
Chairman of the
Committee on Science and the Arts.

APPENDIX.

The following table, accompanying the description of the 'Econometer" furnished your committee, shows the loss of heat and fuel with from 2 to 15 per cent. of carbonic acid gas in the combustion gases:

For coal of medium quality.

If the "Econometer" shows	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Per cent. carbonic acid,
Then the quantity of air passing through the flues is	9·5	6·3	4·7	3·8	3·2	2·7	2·4	2·1	1·9	1·7	1·6	1·5	1·4	1·3	Times the theoretical requirements.
With a surplus supply of air of 30 per cent., or about 10·4 cubic metres of necessary air per kilo. of fuel, there will still be a further excess of about	65·6	40·0	27·2	20 0	15·2	11·2	8·8	5·6	4·8	3.2	2·4	1·6	0·8	0·0	Cubic metres of superfluous air, heated to a temperature of usually 270° C.
And the loss of fuel at 270° C. amounts to .	90	60	45	36	30	26	23	20	18	16	15	14	13	12	Per cent.

One kilogram of anthracite coal of medium quality requires theoretically about 8 cubic meters of atmospheric air.

If, for example, in the case of a steam boiler using a medium quality of anthracite, the econometer shows an average of only 3 per cent CO_2 (a case often happening in practice), then the volume of air used for the combustion of a kilogram of coal and the almost equal volume of gaseous smoke is about $8 \times 6{\cdot}3 = 50{\cdot}4$ cubic meters reduced to the temperature of 0° C.

If the atmospheric air passes to the grate at a temperature of 20° C., and the combustion gases leave the boiler at 270° C., the difference of temperature amounts to 250° C., then the heat carried away by the chimney gases (which, on an average for each degree centigrade per cubic meter, require 0·32 of a heat unit) amounts to $50{\cdot}4 \times 250 \times {\cdot}32 = 4032$ heat units.

Further, if the anthracite coal used has an actual heat value of 7,000 heat units, the loss of heat or fuel loss can be calculated at about

$$\frac{4{,}032 \times 100}{7{,}000} = 58 \text{ per cent.}$$

If with the same firing and with a larger supply of air the amount of carbonic acid falls to 2 per cent., the loss amounts at once to $8 \times 9{\cdot}5 \times 250 \times 0{\cdot}32 = 6080$ heat units, or about

$$\frac{6{,}080 \times 100}{7{,}000} = 87 \text{ per cent. of coal.}$$

RECORD OF TEST OF ECONOMETER AT BALDWIN LOCOMOTIVE WORKS, AUGUST 13, 1897.

Time.	Econom'tr Reading.	Gas Analysis.			Draft M'm.	Memoranda.
		Sample Taken.	Carbonic Acid.	Oxygen.		
P.M.	Per Cent.	P.M.	Per Cent.	Per Cent.		Fired at 2 P.M.
2.04	3·80					
2.05	3·80	2 05	4·02	14·95		Steam pressure 135 pounds.
2.05½	3·80					Fire about 7 inches thick.
2.06	3·80					
2.06½	4·00					
2.07	4·00					
2.07½	4·00					
2.08	4·10					
2.08½	4·10					
2.09	4 00					
2.09½	4·00					
2.10	4·00				7 m.m.	
	3·95 Average.					
2.21	4·70	2.21	4·84	no det.		
2.21½	4·70					
2.22	4·70					
2.22½	4·65					
2.23	4·15					
2 23½	3·40					
2.24	3·15					
2.24½	3·10					
2.25	3 30					
2.25½	3·40					
	3·915 Average.					
2.40	3·80					
2.40½	3·80					
2.41	3 90					
2.41½	3·90					
2.42	3 90					
2 42½	4·00					
2.43	3 90	2.43	4 12	15·46	7 m.m	
2 43½	3·90					
2 44	3·80					
2.44½	3·80					
2.45	3 70					
2.45½	3 60					
2.46	3 50					Fired 2.49 P.M.
	3·81 Average.					Steam jet blower on at 2.54 for 5 minutes.
3.00	8·00					Fired 3 P M.
3.00½	8 60					
3.01	9·10					
3.01½	9·40					
3.02	9·60					
3 02½	9·70					
3.03	9·00	3.03	9 06	10·85	7 m.m.	
3.03½	7·00					
3.04	6·80					
3.04½	7·20					
3.05	8·00					
3.05½	8 60					
3.06	8·90					
3.06½	9·00					
3.07	8 90					
	8·52 Average.					

RECORD OF TEST OF ECONOMETER AT BALDWIN LOCOMOTIVE WORKS, AUGUST 13, 1897.

Time.	Econom'tr Reading.	Gas Analysis.			Draft M'm.	Memoranda.
		Sample Taken.	Carbonic Acid.	Oxygen.		
P.M	Per Cent.	P.M.	Per Cent.	Per Cent.		Blower on 3.15 P.M.
3.23	11·00					
3.23½	11·00					
3.24	10 90					
3 24½	10 80					
3.25	10·50					
3.25½	10 50					
3 26	10·40	3.26	10·53	8 38	8 m.m.	Fired 3.26 P.M.
3.26½	10 30					
3.27	10·10					
3.27½	9·80					
3.28	9·70					
3 28½	9 60					
	10·38 Average.					
3.40	8·70					
3 40½	8·90					
3.41	8·80					
3.41½	8·70					
3.42	8·40					Blower off 3.42 P.M.
3.42½	7·90					
3.43	6·80	3.43	6·57	not det.	7 m.m.	
3.43½	6·00					Fired 3.44 P.M.
3.44	5·50					
3.44½	5·10					
3 45	4 80					
3.45½	4·60					
	7·02 Average.					
3.54	4·00					
3.54½	4·00					
3.55	4·00					
3.55½	4·00					
3.56	4·10					
3.56½	4·30					
3.57	4·50	3.57	4·38	15·10		
3.57½	4·40					
3.58	3·80					
3.58½	3·30					
3.59	3·00					
3.59½	3·10					
4.00	3·50					
4.00½	4·00					
	3·857 Average.					

[NOTE—The "Econometer" readings inclosed in braces are those taken during the time of drawing the samples for chemical analysis.]

GRAPHICS OF THE THERMODYNAMIC FUNCTION.

BY WILLIAM FOX,
Assistant Professor of Applied Mathematics.

On reading Professor Thurston's article on the "Graphics of Thermodynamic Law,"* I thought that it might interest students of the subject to see that graphics can be applied even to the mystical function ϕ and to all theorems depending on it.

We start with equation (9) of Dr. Thurston's article:

$$d H = K_v \, d t + t \, \frac{d p}{d t} d v \tag{1}$$

From the "defining" equation of a gas, $p \, v = R \, t$, we readily obtain

$$p \left(= t \, \frac{d p}{d t} \right) = \frac{R \, t}{v} \tag{2}$$

and hence

$$d H = K_v \, d t + R \, t \, \frac{d v}{v} \tag{3}$$

and

$$\int'' d H = K_v \int'' d t + R \int'' t \, \frac{d v}{v} \tag{4}$$

which can be solved only when we know the law of variation between t and v, or when either t or v is constant.

Dividing equation (3) by t, we get

$$d \varphi = \frac{d H}{t} = K_v \, \frac{d t}{t} + R \, \frac{d v}{v}. \tag{5}$$

and

$$\begin{aligned} \varphi = \int \frac{d H}{t} &= K_v \, hyp.\, log.\, t + R \, hyp.\, log.\, v + C \\ &= hyp.\, log. \, (t^{K_v} \, v^R) + C \\ &= hyp.\, log. \, (t \, v^{\gamma - 1})^{K_v} + C \end{aligned} \tag{6}$$

* *Jour. Frank. Inst.*, **141**, 27.

The quantity ϕ may also be expressed as a function of p and v, or of t and p:

$$\varphi = hyp.\ log.\left(\frac{p\,v^{\gamma}}{R}\right)^{Kv} + C \qquad (7)$$

$$\varphi = hyp.\ log.\left(R^{\gamma-1}\frac{t^{\gamma}}{p^{\gamma-1}}\right)^{Kv} + C \qquad (8)$$

As is well known,

$$R = K_p - K_v = \left(\frac{K_p}{K_v} - 1\right) K_v = (\gamma - 1)\, K_v = a\ p_o\, v_o$$

By means of equations, 6, 7, 8, ϕ can be found if any two of the quantities p, v, t are known. If a curve be used to represent a series of changes in the pressure and volume of a given gas, a similar curve can be constructed referred to t and ϕ co ordinates, representing varying values of t and φ corresponding to the different values of p and v, as shown by the curve.

The transforming equations present, however, some difficulty on account of the constant of integration C, which determines the position of the origin of co-ordinates. Apparently ϕ should reduce to zero when t, p or v is equal to zero. We then have

$$\varphi = O = hyp.\ log.\ O + C = -\infty + C \text{ and } C = \infty$$

By placing the origin at a distance C from the true origin at infinity, we can and do disregard the constant. Besides, all calculations deal with differences and variations of the function ϕ, rather than with its absolute value.

Hence

$$\varphi = 0 \text{ when } t_v^{\gamma-1} = \frac{p\,v^{\gamma}}{R} = t^{\gamma}\,p^{1-\gamma} = 1$$

Heat Absorbed during a Series of Changes.—From equation (5) we have

$$t\,d\varphi = d\,H \text{ and } H = \int_{'}^{''} t\,d\varphi \qquad (9)$$

This can be integrated when the law of variation between t and φ is known, or when either t or φ is a constant.

Equation (9) can be represented by an area just as $\int p\, d\, v$ is represented. Let us assume the abscissas to correspond to the values of ϕ and the ordinates to represent values of t (*Fig. 1*).

In adiabatic expansion the value of H—the actual heat absorbed during expansion—reduces to zero, and hence

$$H = \int t\, d\, \varphi = 0 \text{ or } \varphi = \text{constant.}$$

In *Fig. 1*, the straight line $A\ B$ represents adiabatic (isentropic) changes between limits of temperature corresponding to A and B; the straight line $C\ D$ represents isothermal changes between limits of φ corresponding to the points C and D; while the line $E\ F$ may represent any known series of changes between the limits of φ and t corresponding to the co-ordinates of the points E and F.

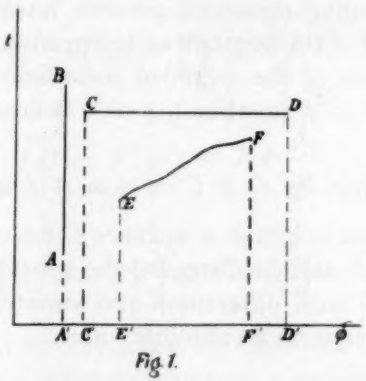


Fig. 1.

The areas $A\ B\ A'$, $C\ D\ C'\ D'$ and $E\ F\ E'\ F'$ represent each the quantity of heat which must be supplied to produce the changes represented by the lines $A\ B$, $C\ D$ and $E\ F$, respectively, *i e.*, values of

$$\int_{\varphi'}^{\varphi''} t\, d\varphi$$

If the series of changes take place in the opposite direction, from F to E, from an initial value of φ to a smaller final value,

then the area will be measured in the opposite direction and will be negative. It will then represent heat which must be abstracted from the changing gas.

Figs. 2 and *3* represent corresponding changes in p and v and t and φ; they give all the particulars concerning the conditions of the gas. P (P') is supposed to be the initial condition, while $P\ I$ ($P'\ I'$), $P\ A$ ($P'\ A'$), $P\ D$ ($P'\ D'$), and $P\ F$ ($P'\ F'$) show respectively isothermal, adiabatic, isometric and isopiestic changes. Line $P\ C$ ($P'\ C'$) shows that heat is given out, although the gas is expanding and doing work; while line $P\ E$ ($P'\ E'$) is absorbing mechanical energy during compression and at the same time requires a supply of heat energy.

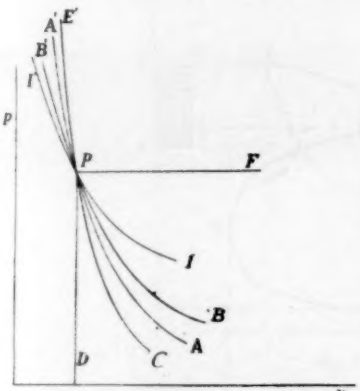


Fig. 2.

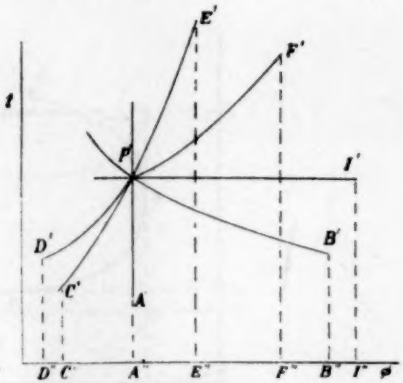


Fig. 3.

Heat Required during Cycle.—A cycle of operation may be represented by a closed figure (*Fig. 4*).

Draw two adiabatics φ' and φ'' and two isothermals t'' and t' tangent to the given area, thus circumscribing it, the points of tangency being the points $A\ B\ C$ and D. Let the changes follow one another in the direction indicated by the arrow in the diagram. The area $\varphi'\ A\ B\ C\ \varphi''$ will represent the quantity of heat which must be supplied during the changes from A through B to C. This quantity,

$$\int_{\varphi'}^{\varphi''} t\, d\varphi,$$

will be positive. In a similar manner the changes from C through D to A are accompanied by a production or evolution of sensible heat represented by the area $\varphi''\ C\ D\ A\ \varphi'$. This area,

$$\int_{\phi''}^{\phi'} t\, d\varphi,$$

will evidently be negative. The algebraic sum of these two areas gives the area enclosed by the irregular line $A\ B\ C\ D$ and represents the total amount of heat which disappears as heat, *i. e.*, is absorbed during the cycle and appears as mechanical energy or work.

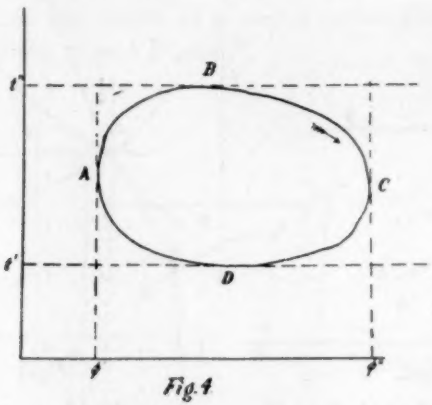


Fig. 4

If, therefore, we chose our units in the two diagrams properly, this area referred to t and φ co-ordinates will be exactly equal to the area of the diagram of a cycle of changes referred to the ordinary co-ordinate axes v and p.

Mechanical Energy.—In order to get an area representing the mechanical energy developed during any changes, such as those represented by the line in *Fig. 5*, we proceed as follows: Area

$$\phi'\ A\ B\ C\ \phi'' = \int t\, d\phi = H = K_v \int d\, t + R \int t \frac{dv}{v}$$

See eq. (4).

where

$$R \int t \frac{dv}{v} =$$

mechanical energy developed.

$$K_v \int dt = K_v (t'' - t')$$

where t' is the initial temperature at the point A', and t'' is the temperature at the point C, the end of the changes.

Draw the line K_v, distant from the axis of t by an amount equal to K_v; then will the shaded area $t'\ t''\ D\ E$ represent $K_v (t'' - t')$.

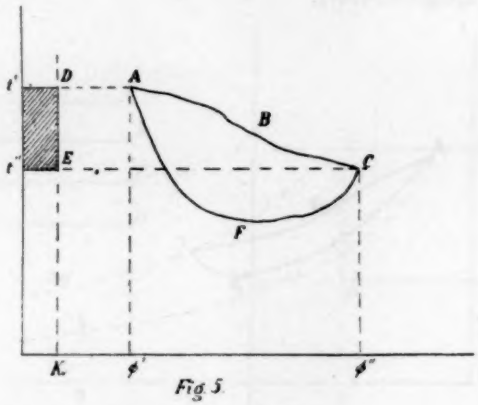


Fig 5.

Hence from equation (4)

$$\int t\, d\varphi - K_v \int dt = R \int t \frac{dv}{v} = \text{work}$$

and area $\varphi'\ A\ B\ C\ \varphi''$ + area $t'\ t''\ D\ E$ = Work.

Here we assumed t' greater than t'', and hence the area $t'\ t''\ D\ E$ is negative, and the work performed is really the arithmetical *sum* of the two areas.

Passing back to A through *any* series of changes as along the line through F, the same area will represent $K_v\ (t' - t'')$, but will be positive since now the final temperature is higher than the initial.

Thus during a *cycle* represented by the successive changes along $A\ B\ C$ and then back along $C\ F\ A$, the work done is

represented by the area enclosed, *A B C F A*, since the two equal areas *E t″ t′ D* with opposite signs counteract each other and disappear in the result.

It is, therefore, evident that any area enclosed by lines representing a series of changes of values of φ and t is *equal* to the corresponding area enclosed by the lines representing varying values of p and v (*Fig. 6*).

Area φ *A B C* φ'' of *Fig. 5* is equal to the area φ' *A B C* φ'' of *Fig. 6*, the curves ϕ' and ϕ'' being extended to infinity; and hence the latter represents the quantity of heat absorbed during the changes along the line *A B C* (Theorem, p. 303, Rankine, Steam Engine, etc.).

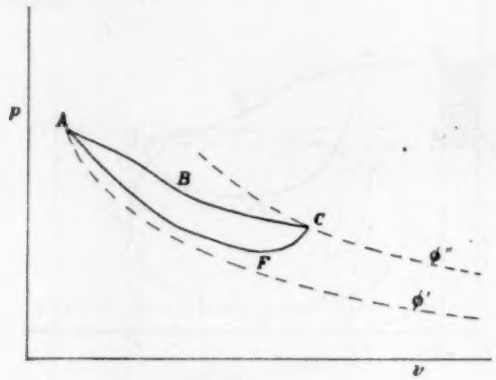


Fig. 6.

The Second Law of Thermodynamics.—The second law of thermodynamics can now also be represented in a simple manner (Rankine, § 244, p. 308). In *Fig. 7*, *A B* represents an isothermal expansion at temperature t; and the area φ' *A B* φ'' represents both the heat absorbed during this expansion as well as the mechanical work performed.

This *area* may be divided into equal parts by simply dividing t into equal parts and drawing the isothermals *C D*, *E F*, etc., *A B C D* = *C D F E* = etc. Hence every part of the temperature affects the work by the same amount.

Carnot's Cycle.—Fig. 8 represents the diagram of the elementary engine (Carnot's cycle). The area $(t' - t'')(\varphi' - \varphi'')$ = *A B C D* is evidently the work performed during the cycle,

while $\varphi'' A B \varphi' = t' (\varphi' - \varphi'')$ represents in the same units the quantity of heat absorbed during and hence required by the cycle. The efficiency of this engine is, therefore,

$$\frac{(t' - t'')(\varphi' - \varphi'')}{t'(\varphi' - \varphi'')} = \frac{t' - t''}{t'}$$

Maximum Efficiency.—*Fig. 9* represents the diagram of any engine, and the circumscribing rectangle $A B C D$ represents the work done by an elementary heat engine acting between the same limits.

The efficiency of the former is the ratio: (Irreg. area, $E F G H I$, etc.) $\div \varphi'' E F G \varphi'$, while the efficiency of the

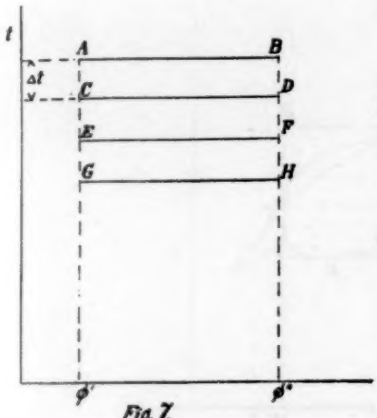


Fig. 7.

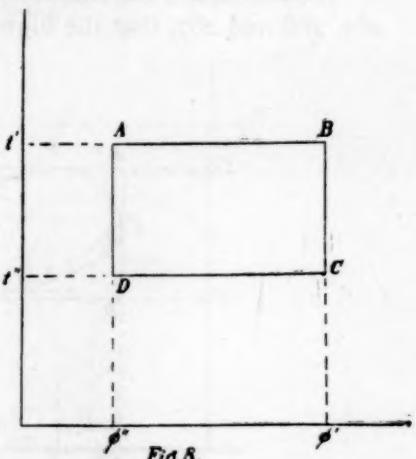


Fig. 8.

latter is the ratio: $A B C D / \varphi'' A B \varphi'$, where $A B C D = E F G H + E F A + F B G + G C H + H D E$ and $\varphi'' A B \varphi' = \varphi' E F G \varphi'' + E F A + F B G$.

Subtracting from both the numerator and the denominator of the fraction $A B C D / \varphi'' A B \varphi'$ the same quantity $E F A + F B G$, we get

$$\frac{E F G H + G C H + H D E}{\varphi'' E F G \varphi'}$$

which is less than the original ratio

$$\frac{A B C D}{\varphi'' A B \varphi'}$$

and hence

$$\frac{E\,F\,G\,H}{\varphi''\,E\,F\,G\,\varphi'}$$

is still less than the same ratio

$$\frac{A\,B\,C\,D}{\varphi''\,A\,B\,\varphi'}$$

(NOTE.—It is easily shown that if both numerator and denominator of a fraction whose value is less than unity be decreased by the same amount, the resulting fraction is reduced in value.)

We thus reach the conclusion given by Rankine, on pages 265, 266 and 267, that the highest possible efficiency between

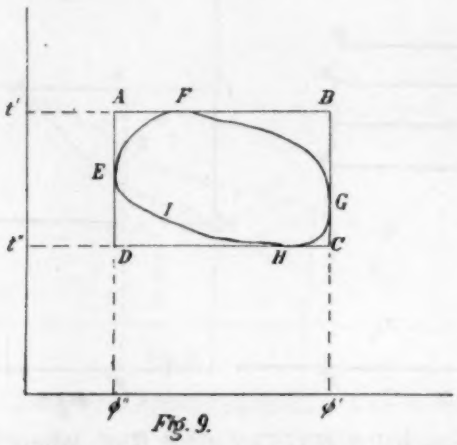


Fig. 9.

given limits t' and t'' is the ratio $A\,B\,C\,D\,/\,\varphi''\,A\,B\,\varphi' = (t' - t'')\,/\,t'$, and corresponds to the efficiency of an elementary heat engine.

Isodiabatic Lines—Regenerator.—Fig. 10 represents isodiabatic lines, which appear simply as lines parallel to each other, or rather as lines equidistant at all points, the distances being measured parallel to the axis of φ.

Points A and D have equal ordinates (temperature t'); similarly B and E correspond to the temperature t''; $A\,B$ and $D\,E$ are parallel. Therefore, the areas $\varphi'\,A\,B\varphi''$ and $\varphi'''D\,E\,\varphi'^{v}$ are equal, and the same quantity of heat is absorbed in chang-

ing from A to B as from D to E, *i. e.*, between the same temperatures t' and t''.

We can readily show that isometric as well as isopiestic lines are isodiabatic.

From equations (6) and (8), we have

$$\varphi = hyp.\ log.\ t^{Kv} + Rhyp.\ log.\ v + C$$

and

$$\varphi = hyp.\ log.\ t^{Kp} + Rhyp\ .log.\ R\ /\ p + C$$

If v is constant, we get the logarithmic curve

$$\varphi_v' = hyp.\ log.\ t^{Kv} + \text{constant } C'$$

depending on the value of v ($= v'$).

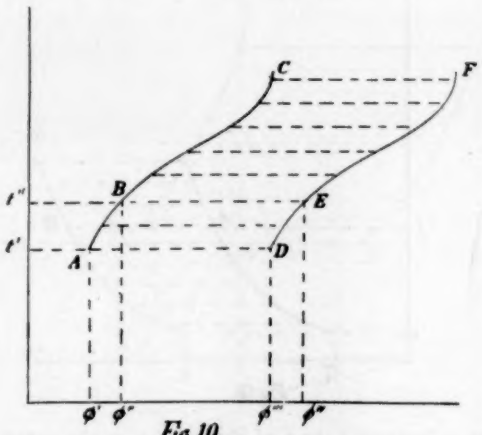


Fig. 10.

For any other value v ($= v''$), we get

$$\varphi_v'' = hyp.\ log.\ t^{Kv} + C''$$

depending on v''.

At equal temperatures,

$$\varphi_v' - \varphi_v'' = C' - C'' = \text{constant.}$$

See distance $A\ B$, *Fig. 11.*

Similar reasoning applies to lines of equal pressure, isopiestic lines.

The area enclosed by two isothermals and two isodiabatics, whose abscissas differ by the constant $\varphi_1 - \varphi_2$, is equal to the

rectangle $(t' - t'')\ (\varphi_1 - \varphi_2)$. This is evident since the area is made up of infinitesimal areas $(\varphi_1 - \varphi_2)\ d\ t$, which, when added, give the total area $(\varphi_1 - \varphi_2) \int d\ t = (\varphi_1 - \varphi_2)\ (t' - t'')$.

Let *Fig. 12* represent such an area $A\ B\ C\ D$. Then the efficiency of such a cycle is represented by the ratio $A\ B\ C\ D\ /\ \varphi'\ A\ B\ C\ \varphi''$, or its equal $A'\ B\ C\ D'\ /\ \varphi'\ A\ B\ C\ \varphi''$, provided all the heat represented by the area $\varphi'\ A\ D\ C\ \varphi''$ is lost as available heat. If, however, the heat given out during the changes from C to D be taken up (absorbed) by a "regenerator" and then returned or re-supplied to the medium while passing from A to B, then the area $\varphi'^{v}\ D\ C\ \varphi''$ represents that heat. To find the efficiency in that case we must subtract this

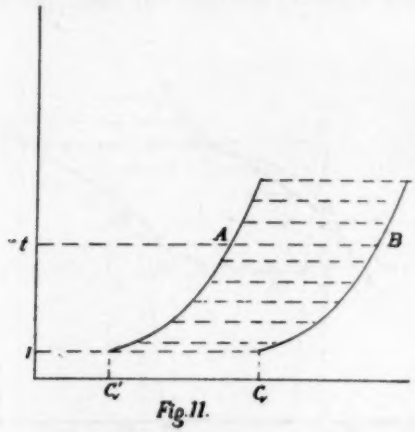


Fig. 11.

area from the denominator of the above ratio. Since the lines $A\ B$ and $D\ C$ are isodiabatic, the area $\varphi'^{v}\ D\ C\ \varphi'' = \varphi'\ A\ B\ \varphi'''$, and hence the efficiency will be

$$\frac{A'\ B\ C\ D'}{\varphi'\ A\ B\ C\ \varphi'' - \varphi'^{v}\ D\ C\ \varphi''} = \frac{A'\ B\ C\ D'}{\varphi'\ A\ B\ C\ \varphi'' - \varphi'\ A\ B\ \varphi'''}$$

$$\frac{A'\ B\ C\ D'}{\varphi'''\ B\ C\ \varphi''} = \frac{t' - t''}{t'}$$

This value $(t' - t'')\ /\ t'$ we recall as the maximum possible between the given limits of temperature (vid. Rankine, § 273, etc.).

We notice that, theoretically, the successive portions of

the regenerator must assume the decreasing temperatures corresponding to the successive points of the line *C D*. During the "regeneration" the temperature of the medium will change in the reverse order, and as the gas passes through the regenerator in the opposite direction, it will encounter temperatures corresponding to its own. Hence a transfer of heat is possible, if the "heat-capacity" (specific heat and mass) of the regenerator is high, and if its different portions are sufficiently "insulated" from each other.

If the lines *A B* and *C D* are not parallel, changes between equal temperatures will require different quantities of heat $\int t\, d\varphi$, and hence a complete transfer will not be possible.

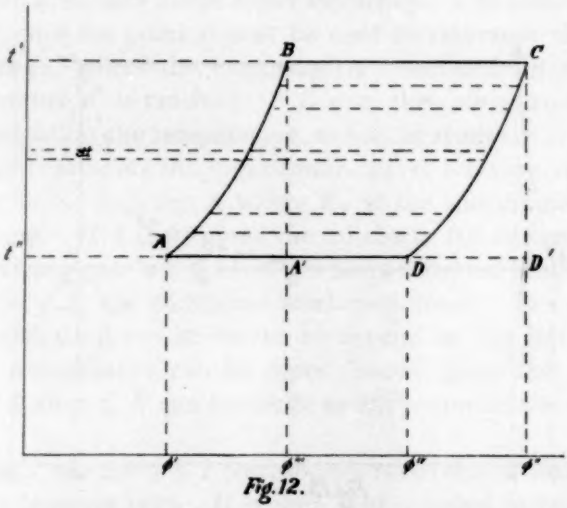


Fig. 12.

Applications.—The advantage of the $t\varphi$ diagram is the fact that it represents by finite areas both the work performed and the heat supplied during a cycle of operations, such as a revolution of the hot-air engine.

The discussion may be made general, but somewhat more difficult, by insisting on the value $d\,p\,/\,d\,t$ instead of $p\,/\,t$ in the original equation, and introducing molecular internal action, as in the case of liquids and imperfect gases.

In that case we can still suppose the variation of φ to be known, and we can still construct the diagram of a cycle.

Since we return to the original condition of the fluid, the enclosed area still represents mechanical energy developed and the area $\varphi'\ A\ B\ C\ \varphi''$ (*Fig. 5*) the heat supplied.

Let us for example apply the $t\ \varphi$ diagram to the steam engine:

In *Fig. 13*, the curve $A\ B$ is logarithmic, and represents the changes in the water as its temperature rises from that of the feed (t'') to the boiling point corresponding to the pressure in the boiler (t'). In the equation:

$$\varphi = K_v\ hyp.\ log.\ t + \int (d\ p\ /\ d\ t)\ d\ v$$

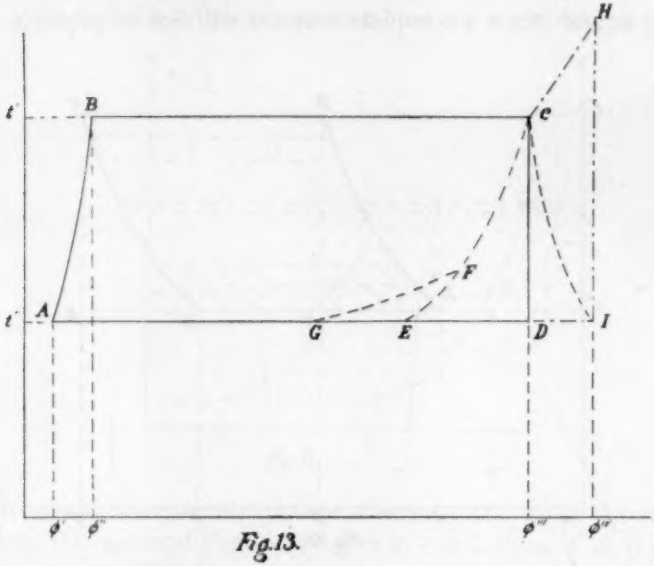


Fig. 13.

v and p are practically constant, and, therefore, $d\ v$ and $d\ p\ /\ d\ t = O$, and hence

$$\varphi = K_v\ hyp.\ log.\ t,$$

where K_v = specific heat of the liquid.

The isothermal from B to C shows the conversion of the water into steam. The heat required, area $\varphi''\ B\ C\ \varphi'''$, is composed of two parts: the mechanical work of expansion of the steam from the volume of the water, and the internal molecular work of disintegration of the water into steam. In other words, it shows the latent heat of evaporation from and at the

given temperature and pressure. The adiabatic $C\ D$ gives the most efficient reduction of temperature, down to that of the feed water, t''. $D\ A$ shows the isothermal recondensation of the steam. Here also the rectangle $A\ D\ \varphi'''\varphi'$ includes simultaneously the energy of compression and that of reintegration into water.

The efficiency of the steam engine is thus seen to correspond very closely to that of Carnot's cycle. Unfortunately, the line $C\ D$ is not attainable in practice, as the water in the expanding steam causes dissipation of energy by facilitating the radiation losses. The function φ is, therefore, diminished, and a curve similar to $C\ E$ ensues, yielding a much smaller enclosed area, and hence lower efficiency. The point C is the cut-off, and the point F may be used to represent the end of the stroke, unless the expansion is continued till the lower temperature t'' is reached. $F\ G$ may then show an isopiestic or other fall in the temperature, as met in reality.

$C\ H$ represents the logarithmic curve, showing superheating; $\varphi = K_v\ hyp.\ log.\ t$, where K_v is the specific heat of the steam-gas. $H\ I$ then gives the adiabatic fall in temperature of the steam-gas. $\varphi'''\ C\ H\ \varphi'^{v}$ is the additional heat required, and $C\ H\ I\ E$, the additional work performed. The economy of superheating can be shown to depend on the fact that the fall in temperature can be more closely along the adiabatic line $H\ I$, than $C\ E$ can be made to approximate the adiabatic $C\ D$.

Lastly, the curve $C\ I$ corresponds to saturated steam at the various temperatures. It is seen that a jacket is required to supply the additional heat measured by the area $\varphi'''\ C\ I\ \varphi'^{v}$.

In a similar manner other topics, presenting greater or less difficulty, can be illustrated and simplified. Thus comparisons between different types of engines and engines using different fluids can be made diagramatically, because the figures show both the work performed and the heat energy supplied, and hence also the efficiency. On the other hand, the $p\ v$ diagram gives only the mechanical energy developed.

College of the City of New York,
New York, September 1, 1897.

CHEMICAL SECTION.

Stated Meeting, of Tuesday, January 18, 1898.

DR. LEE K. FRANKEL, President, in the chair.

THE DETECTION OF SALICYLIC ACID IN FOODS.

(PRELIMINARY NOTE.)

BY F. A. GENTH, JR.

In the examination of foods for salicylic acid, the so-called distillation method, suggested by G. Krause and fully described by Mr. McElroy, is the one most frequently used.

The method is as follows: The mass is pulped with phosphoric acid in a mortar, water added if necessary, and after some time strained through a cloth. About 50 to 75 cubic centimeters of the liquid is then subjected to distillation and successive portions of 5 cubic centimeters each of the distillate collected and tested with ferric chloride. If salicylic acid has been used as a preservative, it will be distilled with the water vapor, and give a violet coloration when ferric chloride is added. In the first portions of the distillate no reactions may be obtained, and in cases where only very small amounts of salicylic acid are present in the article under examination, the reaction in the last portion of the distillate would not be very marked. The methyl ester reaction, which is likewise recommended as a test for salicylic acid, cannot always be obtained when the amount present is small.

No other substances have been known to yield distillates giving similar colorations, or any reactions interfering with that for salicylic acid under the above circumstances.

The writer has recently had occasion to examine a series of preserves, such as jellies, jams, catsup, etc., for preservatives. Among the samples submitted were a number obtained through the courtesy of Food Inspector H. J. Hackett, and were known to be free from salicylic acid or other preservatives. In the examination of these latter samples according to the above described method, a color reaction similar to that

given by salicylic acid was found in all cases. When tested with ferric chloride, the first portions of the distillate showed little, if any coloration, and only as the distillation continued did it become more marked. In many cases the distillation process was not continued to within the last 10 cubic centimeters, but was stopped with over 25 cubic centimeters still remaining in the flask. The coloration in dilute solutions was violet, of about the shade and color of similar ferric salicylate solutions; in more concentrated solutions the color was much redder in the case of the distillate from the pure food, and was found to effectually hide the presence of small amounts of salicylic acid, when added.

The nature of the distillates and the examination of foodstuffs for salicylic acid will be further investigated.

CORRESPONDENCE.

SCIENCE AND THE SOCIETY OF FRIENDS.

The Editor Journal Franklin Institute:

SIR:—In his recent speech at the Bishop McVickar banquet, Mr. Joseph Wharton dwelt on a striking fact, known to the great majority of our citizens, but rarely emphasized. There are few Pennsylvanians who have not observed how frequently the names of Friends appear in the management of our railroad, coal and iron interests; how prominently the influence of Friends has appeared in the workings of the Franklin Institute; how the Friends have quietly and persistently worked for the advancement of science. Mr. Wharton forcibly referred to the debt of chemistry to John Dalton and the obligations of electricity to Thomas Young. He might have added that, when George Stephenson was looked on as a crack-brained empiric, a wealthy Friend advanced the money needed to help the infant locomotive on its way. The influence of the Friends as scientific pioneers is, perhaps, as decided as the influence of the Anglican Church on ecclesiastical music, or that of the Scotch Presbyterians on studies of a

metaphysical character. It is one of the facts in the history of industrial science which no student can fail to observe.

The reason of this scientific aptitude is seldom mentioned; but an adequate cause reveals itself to the investigator. Born in a rough, fighting age, the Society of Friends found the social life of England, indeed of the whole world, leavened with the warlike spirit. The famous Friend for whom this Commonwealth was named was the son of an admiral, and to that fact owed a large share of the court favor which he enjoyed. During the fierce wars with the Dutch in Charles II's time, it was almost necessary for a man who wished to figure in society to make at least one cruise against the enemy. The younger sons of the nobility and gentry sought eagerly for commissions in the army or navy. A drunken, brawling soldier or sailor was more highly esteemed by many, perhaps by a majority of the community, than the most exemplary baker or weaver. It was possible for a runaway apprentice or a friendless orphan to rise to distinction if he enlisted in the ranks or before the mast. Narborough and Shovel rose from cabin boys to admirals. From forecastle to quarter deck was no unusual change. Cut off from war, the energies of the Friends turned to farming, iron mining and various industries which gave opportunity for the talents and application which might have won promotion in fleet or army.

Poor boys, with no relish for martial pursuits, with studious habits and devotional inclinations, often looked to the Church. England's annals tell of many a bright lad, whose craving for knowledge pleased the village parson and the country squire. Such boys were helped in their studies, scholarships made their way less rugged, and, finally, the position of servitor at one of the universities would be held out to them. It required patience and self-denial, as well as industry, to pass through the numerous ordeals of a poor scholar, but it could be done, and George Whitefield and a host of others did it. The son of a mechanic or farmer might hope for a country vicarage or a headmastership, he might become tutor in a nobleman's family or end his days as a fellow in the college where he wrestled with Aristotle's logic or translated St. Augustine's

Confessions. From the prizes of the Church the Friend could receive nothing. He rejected its entire system of worship and government. The existence of a settled, paid ministry was to him a stumbling block, and his scruples, if they excluded him from cockades and garters, also barred the way to lawn sleeves and doctor's hoods.

Youths for whom neither the camp nor the chancel possessed any fascination saw a road to advancement in the legal profession. Blackstone shows his apprehension lest the bar would be largely controlled by persons who had not received a classical education. Industrious boys made themselves useful to attorneys, and gradually built up lucrative practices. Steady lads, who never won the the fame of Coke, yet rivalled him in the severity of their labors, and reached a gratifying degree of success. The Friend, who would not fight, and who would not read the Book of Common Prayer, objected to an oath, and this scruple kept him out of the courts and bade him entertain no hope whatever of public office. A host of public positions tempted other men, but the Friend, who refused to swear before any tribunal, knew that law and politics were not for him. Generations passed before he was allowed to give his simple affirmation in testimony of a fact. His creed banished him from the normal channels of ambition, and from the favorite amusements of society. Bear baiting, cock fighting, the prize ring and many of the sports in which the Merry Monarch's courtiers delighted would have disgusted the followers of Fox and Barclay. It was almost a necessity for the Friends to hew out new occupations and find some work that might test the capacities of their young men. What they have done in botany and metallurgy, in mining and agriculture, in chemistry and electricity requires a volume rather than a newspaper article. The reason of their activity in scientific pursuits is, we think, to be found in the facts to which we have called attention.

ROLAND RINGWALT.

NOTES AND COMMENTS.

THE BEET-SUGAR INDUSTRY.

It is gratifying to be able to note the steady growth of the beet sugar manufacture, which, after numerous fruitless efforts in the past, now appears to be not only firmly founded, but to be assured of a rapid growth. At the close of last year there were in operation in the United States nine factories, as follows: Rome, N. Y., daily capacity, 200 tons of beets; Lehi, Utah, 350 tons; Los Alamitos, Cal., 350 tons; Eddy, N. M., 200 tons; Chino, Cal., 700 tons; Norfolk, Neb., 350 tons; Grand Island, Neb., 350 tons; Alvarado, Cal., 500 tons, and Watsonville, Cal., 1,000 tons. The Spreckels interests are engaged in building, at Salinas, Cal., a factory having 3,000 tons daily capacity, and a dozen other new factories in California, Wisconsin, Kentucky, Iowa and Indiana are projected. This industry, perhaps more than any other, except the strictly chemical industries, is dependent upon skilled scientific superintendence for its successful development, and the circumstance that American capitalists are still largely dependent on foreigners for the machinery and skilled superintendence demanded in the business has proved, thus far, a serious obstruction. These difficulties, however, are being gradually overcome, and it is almost safe to predict that a few years more of systematic effort will suffice to place the beet-sugar industry in a position independent of foreign assistance for its development. W.

PROGRESS IN NAVAL ARCHITECTURE.

The past year witnessed unusual advances in the construction of fast steamships for the Atlantic passenger service. In this field the honors have been carried off by the German shipbuilders, as the record-breaking performance of the magnificent *Kaiser Wilhelm der Grosse*, lately put in service, bears witness.

This superb specimen of naval architecture is being duplicated in a sister ship, the *Kaiser Freidrich*, which has just been launched, and will take her place in the fleet of the North German Lloyd line in the course of a few months. The tendency to increase the tonnage of freight steamers is conspicuously shown by the recent addition to the fleet of the Hamburg-American line of the *Pennsylvania*—the first of several similar ships—with a length of over 600 feet, and a load-line displacement of more than 23,000 tons. Noteworthy in the field of shipbuilding, also, is the circumstance that the "White Star" line has now in course of construction for its Atlantic passenger service, a fast steamer, which will exceed not only in length but in a number of other details the hitherto unequalled *Great Eastern*.

Among the novelties in marine construction which came into prominence last year, should be numbered the "roller" vessels of Bazin, in France, and Knopf, in Canada. The fundamental idea involved in the designs of these vessels is, that a ship will advance more readily by rolling over the surface of the water than by forcing her way through it. The trials of these marine novelties failed to justify the views of their inventors.

ELECTRIC RAILWAYS OF EUROPE.

L'Industrie Electrique has just published a complete list with details of the electric railways now operating on the Continent of Europe and Great Britain. The summary, which we print herewith, shows that Germany is far ahead of any other European country in both the number of electric railways and in the length of mileage, etc. It is interesting to note, also, that Germany has four roads using storage batteries, and France five such roads. Switzerland also makes a very good comparative showing. Considering the number and density of the population of Europe, that continent ought to be a veritable paradise for manufacturers of electric railway apparatus:

	Total Length of Lines in Kms.	Total Power in K. W.	Number of Motor Cars.	Lines with Aerial Conductors.	Lines with Undergr. Cond.	Lines with Central Rail.	Lines with Accumulators.	Total No. of Lines.
Germany	642·69	18,963	1,631	45	2	—	4	51
England	109·42	4,670	168	10	1	6	1	18
Austria-Hungary	83·89	2,589	194	7	2	—	1	10
Belgium	34·90	1,220	73	4	1	—	—	5
Bosnia	5·60	75	6	1	—	—	—	1
Spain	47·00	600	40	3	—	—	—	3
France	279·36	8,756	432	19	1	1	5	26
Holland	3·20	320	14	—	—	—	1	1
Ireland	18·00	486	32	1	—	1	—	2
Italy	115·67	5,970	289	9	—	—	—	9
Sweden-Norway	7·50	225	15	1	—	—	—	1
Portugal	2·80	110	3	1	—	—	—	1
Roumania	5·50	140	15	1	—	—	—	1
Russia	14·75	870	48	2	1	—	—	3
Servia	10·00	200	11	1	—	—	—	1
Switzerland	78·75	2,622	129	17	—	—	—	17
Totals	1,459·03	47,596	3,100	112	8	8	12	150

RAILWAY CONSTRUCTION IN 1897.

The *Railway Age* of Chicago makes the following statement regarding new railway lines built in the United States in 1897:

While the year 1897 has shown larger railway earnings and better business conditions than its immediate predecessors, the marked improvement in the financial outlook did not begin early enough in the year for the completion of many new railway undertakings, and so it now appears that, although

much construction work is under way, the mileage of track actually laid is but little greater than that for the preceding year.

The lowest point in twenty years in respect to railway building was reached in 1895, when only 1,803 miles of track were added, and 1897 has done a little better, the total now reported to us being 1,864 miles. California stands first with 210 miles laid on different roads, and no track was laid in New Hampshire, Rhode Island, Connecticut, Maryland, Kansas, Nebraska, New Mexico, Indian Territory, Arizona, Wyoming and Nevada, and five others barely escaped from this category. At the commencement of 1898 the United States will have 184,464 miles of completed railway.

ELECTRICAL PROGRESS.

On the threshold of the new year Mr. Tesla announces certain important advances in vacuum-tube lighting. He appears to have succeeded in increasing the intensity of the light obtainable from these tubes of highly rarefied gas, many hundred and even thousand times, and believes that he is still far from having attained the limit in the amount of light producible by this method. With this increase in intensity of the light, he claims to have effected, also, a notable increase in economic efficiency. While the details of the system have not yet been disclosed, the improvements realized are said to have been achieved by the gradual perfection of the means of producing, economically, harmonical electrical vibrations of extreme rapidity. In a communication on the subject which has just appeared in the *Electrical Review*, a photograph is shown, made on an exposure of two seconds, with the light of one of those tubes having an intensity of 1,000 candles. This picture is remarkable for the strong contrast of the lights and shadows, suggesting, in this respect, the well-known "flash light" photograph. The bearing of these important advances on the subject of lighting in general is obvious.

The experiments of Lieutenant Squier and Dr. Crehore, who have made use of the alternating current and specially designed receiving and transmitting devices to utilize high speeds in telegraphing, have attracted much attention. The capabilities of their method have been put to test by Professor Preece, the Director of the Telegraphs of the British Government, and the results, which will shortly appear in the *Journal*, are highly encouraging.

The name of Marconi, an Italian experimenter, also figured conspicuously in the electrical journals in connection with the problem of telegraphing without the use of wires. It has been stated that by the method employed by this investigator he has succeeded in transmitting intelligence over a distance of eight miles without the use of wires. For this purpose Marconi utilizes the Herzian vibrations. His system has also been made the subject of special investigation by the British telegraphic service.

No radical changes in telephony were introduced last year, but numerous improvements affecting the efficiency and economy of the service have been introduced. There was also a considerable extension of the long-distance system.

The rapid growth of independent telephone lines during the past year is the most noteworthy incident in connection with the subject. The innovation has been confined principally to the smaller cities of the country, which have heretofore been without the advantages of the telephone, but it is rapidly

extending to the larger cities. The *Western Electrician* mentions among the larger municipalities that have been supplied with an independent telephone service, Detroit, Fort Wayne, Mobile, Sacramento, Cleveland, Baltimore, Newark, Richmond, Norfolk, and others. A large amount of capital is already invested in independent telephony; about 1,100 exchanges are in operation and in course of construction, and 20,000 miles of toll lines owned by the independent companies are completed, while many thousand miles of line are in process of construction.

The substitution of electric traction for steam traction on suburban lines has made steady progress during the year just passed, and, in connection with this phase of the subject, the experiments made by the New York, New Haven and Hartford Railroad on one of its branches, with the third-rail system, has been widely commented on, and generally with favor, as portending the gradual adoption of election traction for certain forms of heavy suburban traffic. The announcement made within the past few days that the elevated railways of New York are to be equipped with this system as soon as the change can be made from steam to electricity, is another evidence of the tendency in this direction.

In electric power transmission there has been a decided advance during the past year, not only in the United States, but also in European countries. The Niagara plant has nearly doubled its former output, and the extension of its service to Buffalo is worthy of special mention.

The great extension of the introduction of the electric motor for miscellaneous uses, especially for the direct operation of machinery, is one of the most significant facts bearing on the future of this type of prime mover. For driving elevators, printing-presses, blowing and exhaust apparatus, machine tools, etc., and especially for transmitting power where the work is intermittent in character, the economy and convenience of the electric motor have gained for it general recognition. W.

METAL AND MINERAL PRODUCTION OF THE UNITED STATES IN 1897.

The *Engineering and Mining Journal* places the total value of the mineral and metal production of the United States at over $762,000,000. The values given in the *Journal's* statistical tables are of the products in their crudest forms—coal at the mine, coke from the ovens, pig iron from the furnace, etc. It is noted that the value of the annual product of the United States in 1897 exceeds that of any previous year; also, it greatly exceeds that of any other country, and nearly equals that of all Europe.

The *Journal* says: "The production of 1897 emphasizes not only the great total value, but also the immense variety of the mineral production of the United States. Not only is this country the largest producer of iron and steel, of copper, of lead, of silver and of gold, but almost every mineral and metal known to commerce is found within our borders, and is mined or prepared in some quantity."

We give from the same authority a few only of the more important items:

The production of gold in the United States in 1897 was 2,685,000 fine ounces, valued at $55,498,950, an increase in value of about two and a quarter

million dollars over 1896. The State of Colorado, it is worth noting, largely increased its gold production and now has the largest output of any State in the Union. The production of silver amounted to 56,117,000 ounces, of the value of $33,557,966, a decrease of about two million ounces in quantity, and of about five and a half million dollars in value, as compared with 1896.

The production of copper in 1897 reached 475,338,340 pounds, an increase of nearly eight million pounds over 1896.

The output of lead was 194,532 short tons, valued at about $14,000,000, a substantial increase over the previous year.

The aluminum industry received a decided impetus last year, the production rising from 1,300,000 pounds, valued at $520,000, in 1896, to 4,000,000 pounds, valued at $1,542,240, in 1897.

The output of coal was, in round numbers, 194,500,000 tons, of which 49,500,000 tons were anthracite and 145,000,000 bituminous. The aggregate value of this production was $205,500,000. Large as this output is, it is still below that of Great Britain.

Of coke we produced 11,774,000 short tons, of the value, in round numbers, of $21,500,000.

Of iron ore our production was 17,846,000 tons, of which 12,550,000 tons was from the Lake Superior region.

The production of pig iron was 9,491,796 tons, a large increase over 1896, and the largest output ever before reported. The figures for the production of steel are not yet available, but they will probably reach 6,500,000 tons. Noteworthy is the circumstance that the production of open-hearth steel is advancing rapidly and at present forms about 25 per cent. of our total product. All of this form of steel is used in structural work of various kinds. Other notable items in connection with the iron and steel industries are the successful inauguration of the basic steel process in the Birmingham district in Alabama; the adoption of the improved Hoffman coke ovens by one of the largest Pennsylvania steel works, and the tendency on the part of the great iron and steel works towards the enlargement of the size and capacity of blast furnaces, and the reduction in all directions of costs of production by the adoption of improved methods of handling material. The direct consequence of these circumstances and the concentration of the business of mining and transporting ores, is seen in the fact more generally known that the various finished products of iron and steel are now made in the United States more cheaply than in any other country. The development of a considerable and and constantly growing export trade in these products is one of the most creditable and gratifying symptoms of our present industrial situation.

A decided increase in the domestic production of tin and terne plates in 1897 is a gratifying fact to notice. Special Agent Ayer's report shows the production during the fiscal year ended June 30, 1897, was 446,982,063 pounds, of which about 88 per cent. was of the class weighing lighter than 63 pounds per 100 square feet.

This is an increase in production of nearly 140,000,000 pounds, or over 45 per cent., as compared with 1896. The total importation during the year was 244,407,601 pounds, and the exportation for the same period 139,946,130 pounds, making the net imports 105,161,471 pounds. The production of the United States, therefore, was more than four-fifths of the entire consumption.

The annual capacity of mills completed and in process of construction, June 30, 1897, is said to be about 650,000,000 pounds. The production of black plates aggregated 436,438,035 pounds, an increase for the year of 102,423,237 pounds.

The permanent establishment of this important industry is now an accomplished fact, and it is even asserted with confidence that within a very few years American manufacturers will have succeeded not only in fully supplying our domestic requirements, but also to compete in foreign markets for the disposal of a considerable surplus. W.

BOOK NOTICES.

The Entropy-Temperature Analysis of Steam Engine Efficiencies, with a Blank Diagram Arranged for Easy Application to any Concrete Case. By Sidney A. Reeve, M.E., Adjunct Professor of Steam Engineering at the Worcester Polytechnic Institute, New York. Progressive Age Publishing Company. 1897. Twenty pages.

We have long been using hydraulic analogies for forming conceptions of electrical phenomena. The first half of Mr. Reeve's book gives us a welcome hydraulic analogy for the cycle of a heat engine. He represents the working substance of the engine as a water-wheel carrying buckets full of entropy from a high level to a low one.

In the second part of his book he gives a very elegant graphical solution of the problem of changing an ordinary pressure-volume indicator card into a temperature-entropy diagram. The various losses in the cylinder are then determined from this diagram.

Temperature-entropy diagrams have been attracting much attention lately, but Mr. Reeve's method involves less labor than any other that we have seen. It may be performed by one unfamiliar with the calculus. Other articles on this same subject have appeared during the last few years in London *Engineering*, for December 6 and 20, 1895, and for January 3 and August 14, 1896. The question was treated at the spring meeting of the American Society of Mechanical Engineers, in the discussion of the paper on "Adiabatics. A more extensive treatment, by Prof. M. J. Bonevin, of the University of Ghent, may be found in the *Revue de Méchanique*, January to June, 1897.

E. T. C.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1898.

MR HENRY R. HEYL, in the Chair.

Present, 78 members and visitors.

Additions to membership since last report, 14.

The resignations of Messrs. George H. Frazier and Samuel M. Vauclain from the Board of Managers were filled by the election of Messrs. Stephen Greene and Henry Howson.

Prof. L. F. Rondinella, Chairman of the Committee on Science and the Arts, gave a brief *résumé* of the Committee's work. He called attention to the fact that the condition of the several medal trust funds controlled by the Institute would warrant the grant of a considerably greater number of such awards than the Institute had been giving during the past few years. It would be a great help to this end if the members of the Institute would recommend to the Committee on Science and the Arts subjects for the investigation in the form of discoveries, inventions, etc., of sufficient merit to be deserving of such recognition. The chairman earnestly requested the members to assist the Committee by transmitting suggestions of this nature through the Secretary.

The paper of the evening was presented by Dr. Leonard Waldo, of Bridgeport, Conn., on "The Evolution and Present Manufacture of the American Bicycle." The paper was profusely illustrated by means of models of machines of various types dating from the early part of the present century down to the most improved types of the present time, and by numerous lantern slides, exhibiting the historic development of the bicycle and the elaborate and refined processess of manufacture employed in the representative American factory devoted to this industry.

At the close of the paper, the thanks of the meeting were voted to Dr. Waldo for his interesting and extremely valuable communication, which was referred for publication in the *Journal*, and the subject was referred to the Committee on Science and the Arts for investigation and report.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held February 2, 1898.*]

MR. JAMES CHRISTIE in the chair.

Prof. L. F. Rondinella was elected Chairman of the Committee for the year 1898, and assumed the chair. The retiring chairman received a vote of thanks for his services.

Reports on the following subjects were considered :

Franklin Institute Grand Medal.—Further discussed and held under advisement.

Wave Motors.—Henry Lotzgesell, Philadelphia. Referred back to sub-committee.

The following were adopted:

Compound Locomotive Engine.—Clifton L. Reeves, Trenton, N. J.

ABSTRACT.—This invention is the subject of U. S. Letters-patent No. 585,331, June 29, 1897. It describes a 4-cylinder engine, two of which are inside and two outside the frame. In the one described the high-pressure cylinders are outside. The cranks are set opposite each other for each high- and low-pressure cylinder. The engine is supplied with the regulation balance valves, vacuum valves, live-steam valves, etc., all of which are well known in locomotive practice. The report concedes neither substantial novelty nor utility to the invention. [*Sub-Committee.*—Henry F. Colvin, chairman; Wilfred Lewis, Wm. Penn Evans.]

Steel-lined Aluminum Culinary Ware.—Romaine C. Cole, New York.

ABSTRACT.—This invention (see U. S. Letters-patent No. 513,762, January 30, 1897) describes a culinary vessel consisting of two metals, sheet steel and aluminum, drawn or stamped one within the other, the aluminum forming the inside and the steel the outside of the vessel. The advantages claimed by the inventor are, substantially, that to enable a vessel to cook quickly and to prevent scorching or burning of the food, the walls of the vessel should be of two or more layers, the outer one having a lower specific heat and lower thermal conductivity. Hence his proposal to form such vessels of the two metals above named in the manner above described.

The report of the Committee is unfavorable to the invention for the following reasons:

(1) Want of novelty; the stamping or drawing of one metal within another for substantially similar purposes being fully disclosed in U. S. Patent No. 60,770, January 1, 1867, to Phillip P. Meyer. (2) The claim to advantage on the score of using metals of different specific heats is denied, and that of the beneficial effect in preventing scorching or burning of food, it is affirmed, can be realized equally as well with vessels made from a single layer of aluminum. This advantage, admitting that it exists, does not depend, therefore, on the vessel being made of several layers. (3) The report finds the vessels mechanically defective, in that there does not exist in the samples submitted for examination the "intimate contact" claimed as a feature of the invention; neither did they exhibit the needful water-tight connection of the metals at the rim. "Both air and water, therefore, enter between the two layers forming the vessel, and when the latter is heated the bottom is deformed by the gases, tending to the destruction of the vessel." (4) There appears to be no advantages in these vessels over those of plain sheet aluminum on the score of cost. For these reasons the report is not favorable to the inventor's claim to novelty and utility. [*Sub-Committee.*—Charles James, Chairman; Geo. C. Reese, Joseph Richards, Oberlin Smith.]

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, February 15th, Dr. Lee K. Frankel in the chair.

Mr. Edward H. Earnshaw, Chemist to the United Gas Improvement Company, presented a paper on "The Chemical Composition and Analysis of Water Gas." The paper was freely discussed, and was reported for publication.

ELECTRICAL SECTION.—*Stated Meeting* held Wednesday, February 23d, Mr. Walter E. Harrington in the chair.

Mr. Herbert Laws Webb, of New York, presented a paper on "The Telephone Exchange," illustrated with numerous lantern slides. Referred for publication.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, February 9th, Mr. A. E. Outerbridge, Jr., in the chair. Mr. Paul Kreuzpointner, Testing Department, Pennsylvania Railroad, Altoona, Pa., read a paper entitled "The Practical Aspect of Present Methods of Testing Iron and Steel," illustrated with the aid of lantern slides and specimen test-pieces. Discussed and referred for publication.

Special Meeting of Thursday, February 24th. This was a joint meeting of the Section, and the Numismatic and Antiquarian Society of Philadelphia, Mr. A. E. Outerbridge, Jr., in the chair.

Captain E. L. Zalinski, U. S. A., presented a communication on "Japanese Swords." The subject was illustrated by the exhibition of a number of these weapons, among them several of very ancient date. The paper elicited considerable discussion, and was referred for publication.